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Determinants of Small Business Innovation Research Performance

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DETERMINANTS OF SMALL BUSINESS INNOVATION RESEARCH PERFORMANCE

THESIS

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Abstract

This analysis shows that the Air Force SBIR Program has seen a high rate of failure (over 91%) in Phase II efforts that have completed funding within the last three Fiscal Years. The Joint Capability Area assignment process and subsequent analysis identified several high and low performing groups. Force Integration, Battlespace Awareness, and Protection JCAs were top performers while Command/Control, Logistics, and Force Application were low performers. Additional analysis showed that small businesses have more than double the commercialization rate of large businesses. The commercialization rates for businesses with 150 employees or fewer is 9% while the rate for businesses with greater than 150 employees is only 4%.

Readability statistics were calculated for the requirements of each SBIR project in the data set. For the maintenance and sustainability subset, it seems that readability correlates with success. However, there are other effects at play that result in a reversal of behavior for the larger set. In the logistic regression model, readability was found to have a significant impact of the commercialization rate, but the direction of the effect was the opposite of what was originally hypothesized.

These findings provide the Air Force SBIR Program focus areas to concentrate funding or attention, to improve the commercialization rate, and to ultimately improve the return on investment for a program that utilizes almost $1 billion in annual DoD funding.

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To Wife and Sons

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Ethan E. Blake

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DETERMINANTS OF SMALL BUSINESS INNOVATION RESEARCH PERFORMANCE

I. Introduction

Innovation is a process that involves the generation, adoption, implementation and incorporation of new ideas, practices, and artifacts (Van de Ven et al., 1989). This process is important because it has the potential to drive economic growth and international competitiveness (Balzat, 2006). With this idea in mind, the Small Business Innovation Research (SBIR) program exists to enable domestic small businesses to engage in Federal Research and Development that has the potential for commercialization. Through a competitive awards-based program, SBIR allows small businesses to explore their technological potential and provides the incentive to profit from its commercialization (U.S. Small Business Administration, 2018). Known as "America's Seed Fund," SBIR works to stimulate high-tech innovation and entrepreneurial spirit in the United States as it meets its specific research and development needs.

As of 2019, eleven Federal agencies participate in the SBIR program. These agencies are shown in figure 1. The DoD alone obligates nearly a billion dollars per year in SBIR funding.

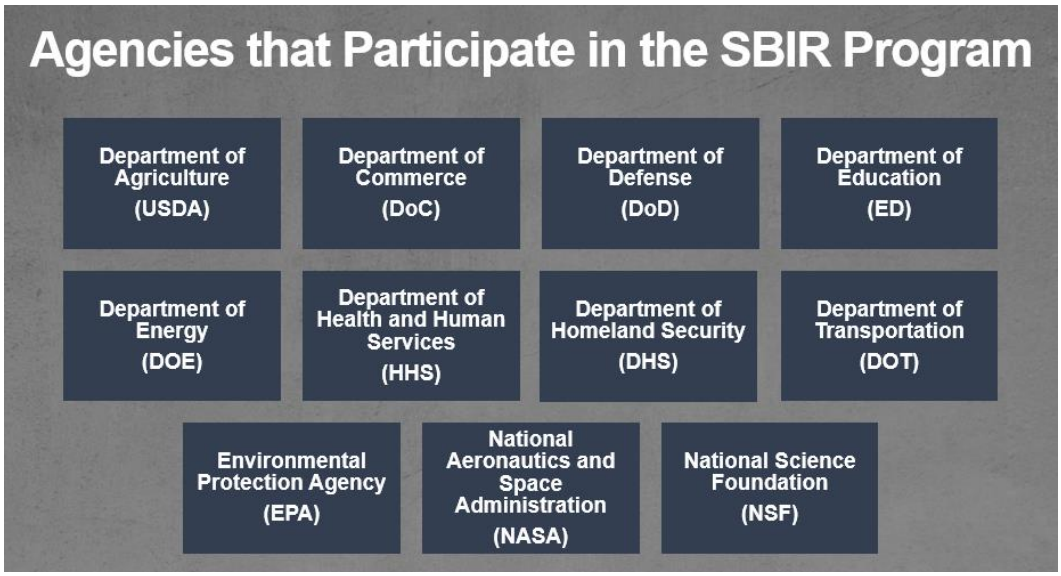


Figure 1. SBIR Participating Agencies (U.S. Small Business Administration, 2019)

There are three phases of the program. Phase I establishes the technical merit, feasibility, and commercial potential of the proposed project. Awards for Phase I typically do not exceed $150,000 for six months. In phase II, the scientific and technical merit are assessed as well as the potential for commercialization. Awards in this phase normally do not exceed $1,000,000 for two years. Finally, the objective of Phase III is for the small business to pursue their commercialization objectives. The SBIR program does not fund this phase. A business' SBIR project is considered successful when their product is commercialized. In other words, the project is a success when it is funded by governmental or commercial sources outside of the SBIR program (United States Department of Defense, Office of Small Business Programs, 2018). It was recently determined that only eight percent of Air Force SIBR projects were able to achieve success from 2015 to 2018 (Rask, 2019).

1.1 Problem Statement

Successful SBIR projects have the potential to drive economic growth and international competitiveness. However, the Air Force SBIR program netted a success rate of only eight percent from fiscal years 2015 to 2018 (Rask, 2019). Failed projects still have value, and important contributions outside of a commercialized product are often a result. Nevertheless, SBIR projects that do not produce a commercially viable product do not meet the primary intent of the SBIR program. It will be important to study the characteristics of the successful and unsuccessful projects to determine whether there are any common trends within each area. If we can determine factors that could increase the success rate of the Air Force SBIR program and make changes accordingly, we will increase the capability that is returned to us through our investment.

1.2 Research Objectives

1) Examine patterns within the SBIR data set to determine:

- Commercialization performance behaviors
- Insight into existing policy performance

2) Expand an existing SBIR commercialization data set for broader analysis that allows for:

- Examination of project characteristics within homogenous areas
- Calculation of readability statistics and other relevant metrics
- Comparison of new entrants and repeats
- Comparison of businesses as a function of size

1.3 Research Focus

The focus of this research is on factors that lead to heightened commercialization rates for Air Force Phase II SBIR projects. Two key analysis are considered, success factors within homogenous segments of the investment portfolio and the effects of requirement clarity.

This research follows-on from previous research that established a baseline performance for SBIR projects (Rask, 2019). The previous research segmented the portfolio based on capability areas: thus allowing a consideration of success factors within a more homogenous set. The data set is diverse, with projects spanning space situational awareness to corrosion prevention. The ability to narrow the set to homogenous segments reduces conflicting factors across diverse segments and allows for pattern recognition within specific segments.

Further, during the effort to segment the baseline portfolio, the clarity of quality of SBIR topics (e.g. requirements) were variable. Due to the importance of requirements on achieving project objectives, objective measures of requirements were considered.

1.4 Research Questions

1) What behaviors or patterns exist among successful Air Force SBIR projects?
2) What behaviors or patterns exist among unsuccessful Air Force SBIR projects?
3) What methods can be developed to investigate and explain those behaviors and patterns?
4) How do patterns differ when projects are homogenous versus heterogeneous?
5) What recommendations can be made to improve the success rate of Air Force SBIR projects?

1.5 Methodology

1) Acquire a data set of Air Force SBIR program commercialization data from Fiscal Year 2015 to July 2018.

2) Correct the data set for any errors

3) Expand the data set to include quantitative assessments of requirement clarity for each project

4) Expand the data set to include historic contract data for SBIR entrants

5) Perform within segment analysis and cross segment analysis of population to determine trends with respect to commercialization.

6) Where possible, identify patterns that can inform investment tactics

7) Identify new and interesting commercialization trends for future research.

1.6 Assumptions

It is assumed that the SBIR program has not undergone any significant changes from the time that the data set was obtained in July of 2018 to the completion of this thesis document that would impact to the integrity of the data. Discussions with the research sponsor support this assumption, and the program has maintained stable management for the time frame in question.

Another assumption is that the portfolio segments are homogenous enough to reduce variability and support the observation of patterns.

1.7 Limitations

1) The SBIR program data set consists of only Air Force SBIR programs from Air Force Fiscal Year 2015 to July 2018.

2) SBIR programs within the data set that failed to include adequate cost, date, or requirement data to determine Phase II contract closeout were excluded from analysis.

3) Commercialization dollars are the only examined success factor. The intrinsic value of diffused technology from SBIR efforts is not analyzed.

4) The readability statistics used in this effort only account for average syllables per word and average words per sentence

1.8 Implications

This research will provide deliverable products to the Air Force Small Business program office to support future research. It will provide the results of an analysis and useful findings for understanding the determinants of SBIR project successes and failures. Additionally, this research adds new data fields for the existing SBIR baseline data, augmenting a data set that serves as a baseline for innovation performance.

II. Literature Review

2.1 Chapter Overview

This chapter offers insight into past research focused on the topic of innovation within the defense industry. It also provides the background, purposes, and processes of the Small Business Innovation Research (SBIR) program on which this thesis builds. Next, it will examine the literature on measuring textual requirements and the methods therein. Additional information on terminology and definitions in these areas are essential to provide the foundation needed to understand the purpose and goal of this thesis research.

2.2 Innovation within the Defense Industry

Before the turn of the century, research conducted by the Department of Defense (DoD) regularly produced significant technological innovations for the civilian sector. Since then, however, commercial innovation has increasingly outpaced the DoD. The national security of the United States greatly depends on our ability to gain access to and make the best use of these commercial innovations. According to the 2018 National Defense Strategy, "Success no longer goes to the country that develops a new technology first, but rather to the one that better integrates it and adapts its way of fighting" (Department of Defense, 2018). Now that the focus of the DoD is shifting back to the rival powers of Russia and China, our ability to compete in this area is more important than ever before. Innovation is a force multiplier that the DoD cannot do without. The DoD must overcome the challenge of attracting innovators and bringing their ideas to fruition in a way that enhances the capability of our armed forces and provides a spark for the United States' economy. One of the primary ways the DoD attempts to accomplish this is through Defense Innovation Programs. The chief of these programs is Small Business Innovation Research (SBIR).

2.3 Small Business Innovation Research

The Department of Defense has known for many years that the success of America's armed services demands ongoing, supported collaboration with private sector innovators (Bresler, 2018). To that end, the Small Business Administration started the SBIR program in 1977 to support innovation through the investment of federal research funds in critical American priorities to build a strong national economy (U.S. Small Business Administration, 2019). Today, SBIR is one of the largest DoD-backed innovation programs in operation. Participation in this program is exclusively available to small businesses. The SBIR size compliance guide defines a small business as a business with 500 employees or fewer. These businesses will respond to capability needs advertised by the DoD. If it is believed that a business has the potential to produce a viable product to meet a capability need, then the business will start its journey through a three-phase program.

In Phase I of the SBIR program, the business is given $150,000 in federal funding. With this funding, the business is expected to establish the technical merit, feasibility, and commercial potential of their project over the course of six months to one year. If there is sufficient evidence that the project has the potential for commercialization after one year, the business will advance to Phase II. For this phase, the business will be given additional funding of up to $1 million. They will continue to grow and develop their technology over a two-year period. At the end of the two-year period, businesses that are still perceived to have a product with commercial potential can move on to Phase III.

The SBIR program does not provide any additional funding for Phase III, rather the business seeks funding from outside agencies or other sources to support additional development or purchase. This phase is intended to be the primary means of transitioning new technologies into the broader service branches or agencies that need them (Bresler, 2018). Once a business has secured funding from outside sources, their product is considered "commercialized" or successful and the SBIR

process is complete. This is how it typically works for the Air Force, but here is a breakdown across the participating agencies:

DoD Component	Cost	Duration	Phase I Option	Discretionary Technical Assistance
Army	Base NTE $100,000 + Phase I Option NTE $50,000	6 Months + 4 Month Option	Required	$5,000
Navy	Base NTE $125,000 + Phase I Option NTE $100,000	6 Months + 6 Month Option	Required	$5,000
Air Force	Base NTE $150,000	12 Months	No	No Assistance
DHA	Base NTE $150,000	6 Months	No	No Assistance
DLA	Base NTE $100,000	9 Months	No	$5,000
DMEA	Base NTE $150,000	6 Months	No	$5,000
DTRA	Base NTE $150,000	7 Months	No	$5,000
MDA	Base NTE $100,000 + Phase I Option NTE $50,000	6 Months + 6 Month Option	Required	No Assistance
NGA	Base NTE $100,000	9 Months	No	No Assistance
OSD	Base NTE $225,000	6 Months	No	No Assistance
USSOCOM	Base NTE $150,000	6 Months	No	No Assistance

Table 1. DoD Awards and Expectations

2.4 The SBIR Application Process

The first step in the SBIR application process is to determine eligibility. Awardees must qualify as an SBC (500 employees or fewer) at the time of award and at any other time set forth in SBA's regulations by submitting a certification stating their qualifying status. Awardees must also show their plan to complete at least one third of the proposed research in Phase I and at least one half of the proposed research in Phase II. The research must be done in the United States unless the funding agreement officer recognizes a unique circumstance that demands otherwise. If the small business qualifies and these conditions are agreed to, then the business will be eligible to participate.

Next, a succinct commercialization plan must be developed with each proposal for a SBIR Phase II award moving toward commercialization. The elements of this commercialization plan should include company information, customer and competition, market, intellectual property, and financing. Once this is accomplished, the business may identify and match with specific SBIR topics listed within the broader solicitation of opportunities.

At this point, the business can register with SBIR and receive credentials. This will allow them to submit additional documentation such as a business plan, executive summary, cost proposal, and technical proposal. This documentation will go through a peer review process. A rigorous peer review system is used to ensure only the most meritorious scientific proposals are funded (Kelly & Sensenig, 2019).

Finally, a proposal is awarded and the business receives funding to conduct research or develop technology as per the proposal submission. The business is required to provide periodic status reports and minimize deviations from the original agreements such as performance extensions or modifications of funding for increased dollar amounts. The business must also certify

that no “Essentially Equivalent Work” is being submitted to another sponsoring agency (Kelly & Sensenig, 2019). The process, in its entirety is illustrated below:

Figure 2. How to Apply (Small Business Administration, 2019)

Defining project success in terms of commercialization begs the question of whether any patterns or characteristics can be identified among successful projects. A few factors are considered in this research. We will start with requirement quality. The choice was informed by observations with the first phase of research with this data set, specifically:

> "If a research team of Air Force acquisition personnel, several with over 20 years of experience, had difficulty comprehending an Air Force SBIR topic, it could be expected that a prospective SBIR firm would have the same issue. (Rask, 2019)"

One feature that can be analyzed is the textual requirement listed for each SBIR topic. The literature shows that there are several existing methods for measuring the quality of textual requirements, and these are explored next.

2.5 Measuring the Quality of Textual Requirements

In order to reach a desirable solution in the innovation arena, or in any design, the problem must first be well-defined. A person needs to have a robust understanding of the issue they are tackling before they take any action. This is why it is so important for the DoD to write quality requirements.

According to a survey conducted by Scott Kirsner of the online resource *Innovation Leader*, one of the top five biggest obstacles to innovation is an employee's lack of clarity on what kind of innovation they are supposed to be doing (Kirsner, 2018). We cannot expect to attract strong innovators to a given project when they are not able to understand what will be expected of their final product. To address this problem, requirements can be analyzed using quality indicators. The four most frequently utilized categories of indicators are morphological indicators, lexical indicators, analytical indicators, and relational indicators (Genova et al, 2011). This taxonomy of indicators and their subcomponents are summarized below in Table 2.

Indicator Categories	Subcomponents
Morphological	• Size • Readability • Punctuation • Acronyms and abbreviations
Lexical	• Connective terms • Imprecise terms • Design terms
Analytical	• Verbal tense and mood • Domain terms
Relational	• Number of versions • Degree of nesting • Number of dependencies • Number of overlapping requirements

Table 2. Taxonomy of Requirement Quality Indicators and their Subcomponents

Morphological indicators measure text properties from a purely formal point of view without considering the substance of the contents. For example, the first and simplest morphological indicator is the size of the requirement. Size can be measured in characters, words, sentences, or paragraphs. For a quality requirement, the text should be long enough to provide adequate information. However, a requirement that is excessively long likely indicates that the writer does not know what he wants to convey well enough to write it concisely. This idea is

supported by a quote from the French mathematician and philosopher Blaise Pascal in his work *Lettres Provinciales* in which he writes, "If I had more time, I would have written a shorter letter."

Another morphological indicator is linguistic readability. Readability measures the degree of difficulty to read a text, and can be operationalized as a grade level. The readability tools that are used in this research effort are the Flesch readability index and the Flesch-Kinkaid readability score. These tools use metrics such as average words per sentence and average syllables per word to calculate a score for a given text. As a benchmark for later, it should be noted that the average American adult reads at a seventh-grade level according to the United States Department of Health and Human Services. Readability gets at the heart of the problem being addressed here because it is so closely related to understandability. As previously stated, we cannot expect to attract strong innovators to a given project when they are not able to understand what will be expected of their final product.

The second category of indicators for analyzing requirements are known as lexical indicators. These measure properties relative to the contents of the text and require reference information. The reference information is usually a list of user defined terms. One list a user might build is a list of imprecise terms that introduce ambiguities in the requirement. For example, a list of imprecise terms relating to quality might include the words "good," "adequate," or "efficient." Another example would be the use of words like "enough" or "sufficient" to describe quantity (Genova et al, 2011). Lexical indicators could also focus on the number of negative terms in a requirement that make it more difficult to understand.

The third category of indicators are called analytical indicators. These types of indicators require a textual analysis of requirements by means of relatively complex linguistic tools (Genova et al, 2011). An example of an analytical indicator is the use of conditional mood versus future tense. The usage of conditional mood instead of future tense could be a result of the writer's

unconscious desire to express a lower level of need in the requirement (Genova et al, 2011). When a writer makes this mistake, he or she is breaking away from a typical rule of thumb which states that a need should be expressed as one of three levels: essential, convenient, or optional. One more example of an analytical indicator is the use of passive voice which can also lead to a certain degree of imprecision.

Finally, the fourth category of indicators are known as relational indicators. This category is unique because these indicators do not measure properties of individual requirements. Instead, they measure properties of a set of requirements such as the number of overlaps or number of versions of a requirement. If a set of requirements has many versions, this can indicate volatility or instability that could stem from a lack of understanding or insecurity about what is really needed. The stability of requirements directly influences verifiability (Genova et al, 2011).

2.6 Incumbency

Incumbency is a measure of historic interaction with the government. Specifically operationalized as the number of government contracts a company has had. This factor was considered as an extension to the perceived requirements opacity in the first phase of research. Perhaps a company with experience working with the government will better understand requirements with military jargon.

It is reasonable to assume that experience with SBIR could improve the probability of commercialization. Therefore, one would hypothesize that the more SBIR contracts a firm has locked in, the more likely that firm is to innovate and yield a successful product. However, the other side of that coin is that such experience may be a proxy for firms that are known as “SBIR mills” (Link & Scott, 2009). SBIR mills are firms that exist, at least in part, for the purpose of securing SBIR awards. These firms may be less innovative and less likely to commercialize than

less experienced, and perhaps more entrepreneurial, firms that have a passion for an extraordinarily innovative idea and a commitment to seeing it through to commercialization (Link & Scott, 2009). This theory will be tested in this research effort as we gather the data on the number of SBIR projects the businesses have been awarded over the course of their respective lifetimes.

2.7 Barriers to Effective Communication

The word "communication" comes from the Latin "communis," which translates to "common". Therefore, communication can be thought of as a medium for making one idea common to multiple people through verbal, non-verbal, or electronic means. Another definition of communication is "any act by which one person gives to or receives from another person information about that person's needs, desires, perceptions, knowledge, or affective states" (Broni & Velentzas, 2014). Communication requires a sender, a message, and a recipient, and the process is complete when the recipient understands the message of the sender. However, there are always barriers of some kind between recipient and sender that can hinder the original intent of the message. Figure 3 shows this cyclical process:

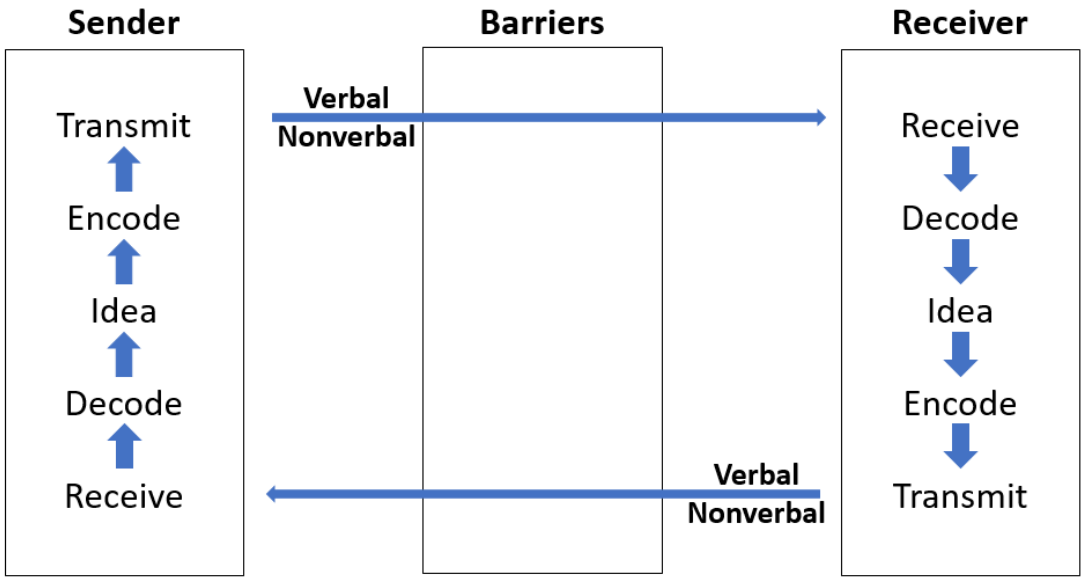


Figure 3. The Communication Cycle

First, the sender has an idea. The sender must encode this idea into something that can be expressed in a way that he or she believes the receiver will understand. The sender then transmits the encoded idea to the receiver. This might happen through one of several mediums, which means the receiver might catch the transmission instantaneously (spoken word) or across space and time (email). Either way, the receiver must then decode the transmission in an attempt to figure out what idea the sender intended to communicate. The hope is that the receiver's resulting idea is the same one originally sent by the sender. This is called effective communication. It occurs when a desired effect is the result of intentional or unintentional information sharing, which is interpreted between multiple entities and acted on in a desired way (Broni & Velentzas, 2014). This effect also ensure the message is not distorted during the communication process. The issue is that many barriers to effective communication exist between sender and receiver.

In the communication cycle, there is the possibility of interference which may hinder the process at any stage. This interference can be called “noise”. To understand the concept of noise, one can imagine communication as a leaky bucket. When a leaky bucket is used to transport water from one person to another, water will be lost at different points along the way. It may be impractical or impossible to completely stop the loss of water because the bucket contains holes. The amount of water lost will be dependent upon the number of holes in the bucket, the size of the holes, and which path is taken to get to the other person. Just as the holes affect the amount of water transferred, more noise decreases the amount of correct information received. Noise can show up in many different forms.

Barriers to effective communication, or noise, can include filtering, selective perception, information overload, emotions, language, silence, communication apprehension, gender differences, and political correctness (Broni & Velentzas, 2014). Another barrier that will play a significant role in this research effort is a lack of knowledge-appropriate communication. A lack of knowledge-appropriate communication occurs when a person uses ambiguous or complex legal words, medical jargon, or descriptions of a situation or environment that is not understood by the recipient. One more similar barrier is the ambiguity of words and phrases. Some words might look or sound the same but have different meanings to the sender and receiver. This can be especially true when two communicators have different backgrounds (such as military and civilian). Therefore, it is the sender’s responsibility to ensure the receiver obtains the same meaning (Broni & Velentzas, 2014).

2.8 Company Size

A final factor considered is the size of the company. This choice was driven in part by the availability of data. It was considered previously by Rask, however, with a fully segmented

innovation portfolio it has been considered again. It is hypothesized that smaller companies will perform better than larger companies, yet what small and large represent is not certain. What is known is that the innovation literature finds improved performance in flat organizations and that the larger an organization becomes, the more likely it is to develop a hierarchical structure that may reduce innovation performance (Kirsner, 2018).

A simple scatter plot of the data set shows the number of employees of a small business versus the number of government contracts awarded to that business (and whether they commercialized), and demonstrates that the smaller businesses are typically more successful than the larger ones. Further analysis shows that companies with 150 employees or less had more than double the success rate compared to companies with greater than 150 employees (about 9% and 4% respectively). This begs the question of whether or not there is anything significant about this tipping point of 150 employees.

In the 1990's, British Anthropologist Robin Dunbar coined the "Rule of 150" when he claimed that there is a cognitive limit to the number of people with whom on can maintain stable social relationships. In the year 2000, author Malcolm Gladwell builds on this idea in his book *The Tipping Point*. Applying the rule to a business environment, Gladwell suggests that only small, close-knit groups have the power to magnify the epidemic potential of a message or idea (such as a particular innovation). People can only handle so much information at once, and we become overwhelmed after we pass a certain boundary. We have a limited capacity for processing raw information, dealing with our feelings, and handling our social channels. The Rule of 150 suggests that the size of a group is a subtle factor that can make a big difference. If we want groups to serve as incubators for contagious messages, then we need to keep the groups below the 150 person tipping point. If not, there will be barriers that keep the group from acting as one body. Beyond this point, groups begin to form divisions and team members become alienated, and this leads to

changes in behavior. When groups are kept small, stronger bonds form among team members and these bonds work to drive performance. Similar to peer pressure, these bonds drive team members to live up to what is expected of them. Knowing people well enough to care about their opinion of you really matters in terms of performance.

Adhering to the Rule of 150 provides a mechanism to make the flow of new ideas and information move through the entire organization rapidly, exploiting the bonds of memory and peer pressure. In order to create one contagious movement, it is often necessary to start by creating many smaller movements. In order to achieve unity and spread specific company ideology to all employees, business must break up into semi-autonomous small pieces. In *The Tipping Point*, Gladwell provides an example of a company that decided to use this strategy long before Gladwell's influence.

Gore Associates is a privately held, multi-million dollar, high-tech firm based in Delaware. Military members will likely recognize them as the developer of the waterproof, breathable Gore-Tex fabric. As the rule demands, Gore Associates divides itself every time employment reaches 150 in any one facility. Since the 1980's, the company has consistently earned a position on Fortune magazine's annual list of the U.S. 100 Best Companies to Work For. Gore Associates is one of 200 largest privately held companies in the U.S. and it employees approximately 10,000 people at more than 50 locations in East Asia, Australia, Europe, and the Americas. Yet, teams never grow beyond 150.

III. Methodology

An objective of this research is to understand factors that lead to SBIR project success with the aim of bettering our portfolio management. In order to do this, the research will compare similar projects to determine commonalities and differences. It is important to compare similar projects so that differences in performance are not attributed to the differences in technology.

Data sources for this project include Air Force SBIR Program Company Commercialization Reports, DoD SBIR Topics, and relevant taxonomies within the Department of Defense. However, the primary data set used was the SBIR Phase II program data set which contains information on 433 SBIR topics with closed contracts reported during DoD fiscal years 2015 to 2018. This data is less than 10 years old and considered to be recent enough to preserve accurate memories of key informants in the Air Force SBIR program office and other relevant offices (in the event follow-on interviews or interaction are required).

A panel of raters used the primary data set to categorize the SBIR topics into 8 Joint Capability Areas. Unlike the data from Rask, this set is the entire population of SBIR topics versus a sampling. It became clear during the coding that there are “hot spot” capability areas in which the majority of SBIR topics tend to fall. These hot spot areas can be seen in the following graphic:

Air Force SBIR Investment "Shots on Goal" Per JCA									
		Joint Capability Area - Tier 1							
		1	2	3	4	5	6	7	8
Joint Capability Area - Tier 2	1	1	3	67	0	0	25	7	4
	2	9	29	26	6	4	6	13	0
	3	1	40		70	2	9	1	0
	4		14		0	1	5		102
	5		2		0	0	42		0
	6		0		4	0			
	7				3				
	8				3				

Figure 4. Number of Air Force SBIR Contracts per JCA

Due to the time limitations of the research effort, it was not possible to analyze all of them. Therefore, it was necessary to narrow them down. Five capability areas were chosen as candidates for analysis based on the following criteria:

(1) High number of topics: *n* greater than or equal to 25

(2) Enough successes and failures to compare: if an area had a high enough number of topics, at least 7% needed to be successes as this is the current success rate for SBIR

(3) Not a “bucket” or catch-all: for example, the PNT area holds only those topics relating to PNT while the RDT&E area holds every topic related to RDT&E that did not logically fit elsewhere.

The 5 capability areas selected as candidates for analysis were:

JCA	Number of topics	Successes/failures	Not a bucket
3.2 Fires (i.e. kinetic)	26	3 / 23 (11%)	x
4.3 Maintenance (i.e. inspect)	70	5 / 65 (07%)	x
6.1 Comm and Computers (i.e. wireless comm)	25	3 / 22 (12%)	x
6.5 Enterprise Services (i.e. PNT)	42	4 / 38 (09%)	x
2.2 Collection (i.e. imagery collection)	29	4 / 25 (13%)	x
TOTAL	192	19 / 173 (10%)	

Table 3. Capability Areas Considered for Analysis

Once 5 were determined, additional selection criteria were created to aid in selection in order to make the data more tractable. From this point, the sponsor chose the category for analysis. The capability area that appealed to the sponsor was JCA 4.3 Maintenance because it plays such a huge role in what we do every day as an Air Force, and so much money is spent there. So, JCA 4.3 Maintenance was the capability area selected for analysis. This capability area had a high number of topics. Additionally, there is a favorable ratio of successes to failures when one considers the 8% success rate of SBIR topics. This capability area did not act as a bucket to catch floating topics that could not find a home elsewhere. When a topic was placed into this capability area, it was a relatively straight-forward decision.

I will also look at the data set as a whole and control for JCA with a set of dichotomous variables. This will be discussed a little later. For the areas selected for analysis, commercialization rates will be investigated. A requirement scale was considered for “goodness of requirements.” The

indicators that were considered to measure the goodness of the requirements are morphological (such as size and readability), lexical (such as imprecise terms), analytical (such as verbal tense and mood), and relational (such as number of versions of a requirement).

Morphological indicators measure text properties from a purely formal point of view without considering contents at all. The morphological indicators that will be measured are size and readability. Size will be measured by total words, and readability will be measured using the Flesch Readability Index and Flesch-Kinkaid Readability Score, methods developed by Rudolf Flesch and J. Peter Kincaid. The Flesch Readability Index (FRI) is a tool that can be used for estimating the reading comprehension level necessary to understand a written requirement. For a given requirement, the Flesch readability index is an integer indicating how difficult the document is to understand with lower numbers indicating greater difficulty. The formula for the Flesch Readability Index is shown below:

Readability = 206.835 – (1.015 x average words per sentence) – (84.6 x average syllables per word)

The Flesch-Kincaid Readability Score is one of the most widely used measures of readability. Like the FRI, it uses word and sentence lengths as metrics, but the output is a grade level. Though the same metrics are used, the two indexes correlate inversely (i.e. a low FRI equates to a high grade level). The formula for the Flesch-Kincaid Readability Score is shown below:

Readability = (0.39 x average words per sentence) + (11.8 x average syllables per word) – 15.59

These methods were developed under contract to the United States Navy in 1975 by J. Peter Kincaid and his team. The methods were first used by the United States Army in 1978 for assessing the difficulty of technical manuals. From there, their usefulness in application expanded to areas of civilian interest such as automobile insurance policies and websites.

The research hypothesizes that commercialization will be more likely when a project's requirements have been written clearly (readability) and the firm has significant experience

working with SBIR (incumbency). The model to test this hypothesis is a logistic regression (logit) model of the probability of commercialization. Commercialization is the dependent variable and is represented as *Comm*. Since a logit model is being utilized, *Comm* will be a dichotomous dependent variable (1 or 0) with 1 representing a firm's successful commercialization of a product or service and 0 representing a failure to commercialize.

This model will include 11 independent variables. The first independent variable is the Flesch-Kinkaid Readability Grade of the requirements solicited for a SBIR topic. This will be represented as *FK_Grade*. I hypothesize that FK_Grade will have a negative effect on the probability of commercialization because requirements written at a very high grade level will be difficult to understand and bring to fruition. Likewise, requirements that are simple and straightforward will likely give innovators a clear scope and understanding of what is expected of them. Initially, FK Grades were going to be calculated manually, but this proved to be too time consuming. Upon further investigation, Microsoft Word was found to have the capability to produce these scores. This product was utilized by following these procedures:

1. Open Microsoft Word
2. Click File, and select Options
3. Click Proofing
4. Scroll down to the section that reads "When correcting spelling and grammar in Word"
5. Under this section, check the box that reads "Show readability statistics"
6. Click Ok
7. Navigate to the Review Tab, and select Spelling & Grammar
8. After errors are addressed, a box labeled "Readability Statistics" will appear. Important data such as FRI, FK Grade level, and other counts and averages are displayed here

An example of a maintenance requirement along with its readability output are shown below:

MX Topic Number 5

> "Management of CONUS-based Integrated Broadcast System (IBS) is structured and adaptation takes time. Transformational Communications Architecture (TCA) supports real-time adaptation through addressable, packet-based communications over the Global Information Grid (GIG) and TCA satellite constellations. Through the GIG/TCA super-

network, commanders can reach fixed resources and POP terminals (JTARS, etc.) for communication to mobile forces. The implementation and integration of network broadcast and multicast information is critical for commanders to disseminate rapid, complete and consistent mission-critical orders, information and data. The advent of SATCOM and wireless networking introduces unique challenges in these communities of interest. Technologies that ensure secure, selective, networked information delivery are key solutions to the above mission challenges, including Over-the-Air (OTR), adaptive algorithm/key management (real-time, secure algorithm/key distribution). The proposal should evaluate solutions to the above problems/issues via the application of new or evolving techniques and developing technologies. Commercial applicability of the above is manifested in the need for similar secure technologies and approaches in the private sector."

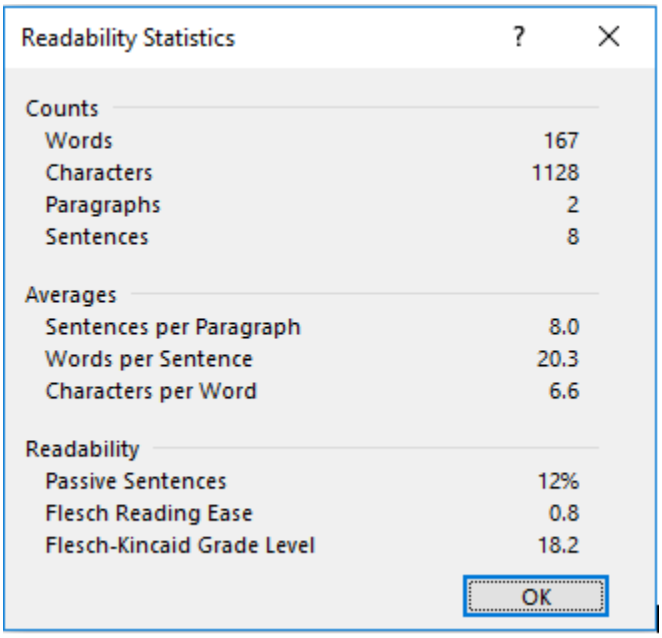


Figure 5. Microsoft Word Readability Statistics Output

The second independent variable is a dichotomous variable indicating whether or not the firm working on the topic has been designated a "Woman Owned" business. This will be represented as *woman_owned*. For this dichotomous variable, 1 will represent that the business is technically owned by a female while a 0 will indicate it is not. I hypothesize that *woman_owned* will have a positive effect on commercialization because businesses with a woman-owned

designation are often eligible for specific grants and low-collateral loans (outside of SBIR) that may give them a significant advantage.

The third independent variable is the number of employees that a business reported for each SBIR topic, represented as *number_employees*. I hypothesize that this variable will have a negative effect on commercialization because of the research relating to the 150 person tipping point. The literature review includes research that shows teams that have grown too large cannot make the connections necessary for this kind of work. It is worth noting that one data point had to be deleted (Topic AF073-051) because the business (Florida Turbine Technologies) was reported as having over 2700 employees. The SBIR eligibility rules state that businesses must have 500 employees or fewer in order to participate. I assume that the 2700 number was either input accidentally or a rule was waived or ignored to allow this company to participate. Either way, I felt that this outlier would erroneously distort my results, so I removed it from the analysis.

The fourth independent variable in this model is the total number of SBIR Phase II contracts that have been awarded to a business over its lifetime. This variable represents the idea of incumbency put forward in the literature review and will be represented as *total_awards*. I hypothesize that this variable will have a positive effect on commercialization. Success in the government world greatly depends on experience. The more that a business has worked with SBIR, the more they will have learned the government languages, work-arounds, and shortcuts. The research indicated that some businesses are just "SBIR mills" and are not necessarily more innovative, but it is still believed that this variable will have a positive effect overall.

The fifth through eleventh independent variables are dichotomous variables indicating which joint capability area (JCA) a topic fits into. There are eight main JCAs, so there will be seven variables and a base case. These will be represented as shown:

Variable Name	Joint Capability Area represented	Comm Rate based on sample
Base Case	Corporate Management & Support	~11%
JCA_1	Force Integration	~22%
JCA_2	Battlespace Awareness	~12%
JCA_3	Force Application	~07%
JCA_4	Logistics	~04%
JCA_5	Command & Control	~00%
JCA_6	Communication & Computers	~08%
JCA_7	Protection	~10%

Table 4. Joint Capability Areas Represented in Logit Model

IV. Analysis and Results

4.1 Chapter Overview

This research effort utilized an Air Force Phase II Small Business Innovation Research (SBIR) data set. The analysis conducted on this data set was performed in order to determine if a pattern of characteristics would emerge among successful or unsuccessful SBIR projects. Readability statistics were calculated for the requirements of each project, and existing statistical methods were explored to look for patterns based on readability and other parameters.

4.2 Data Analysis

First, the maintenance and sustainability area was analyzed independently (no other JCAs included). As part of exploratory data analysis, the successes and failures were plotted in a histogram. The population of all sustainability projects is represented in the histogram below. The successes are overlaid as diamonds on this graph. From this first analysis, it appears that a higher readability score (inversely related to grade level – high score, low grade level) is associated with success. The span indicated below is the difference between the mean readability (22.9) of the failures and the mean of the successes (31.8).

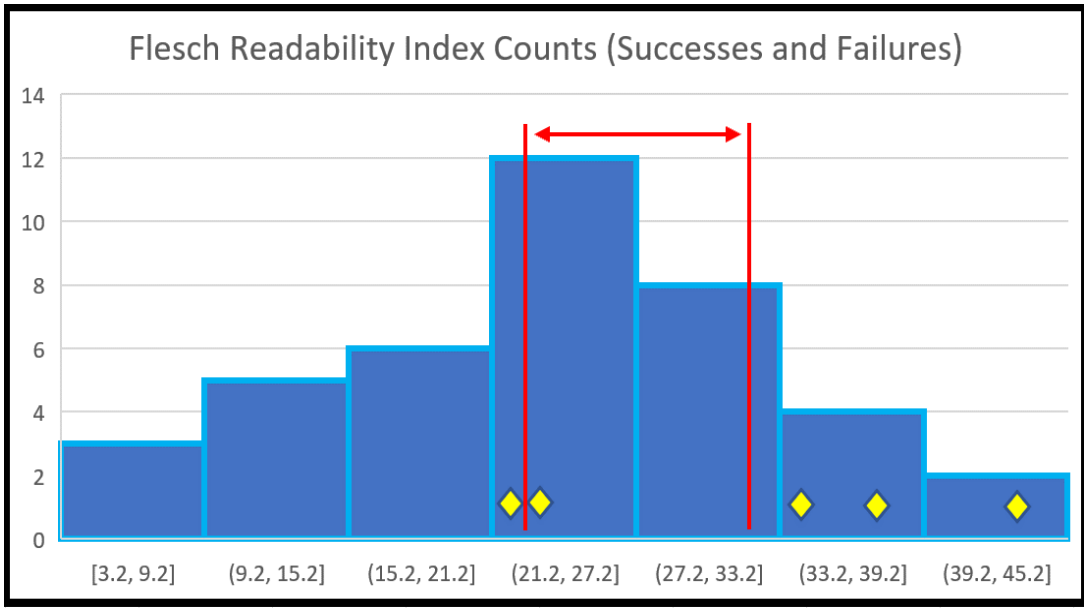


Figure 6. Sustainability Data Set Histogram – Successes Highlighted – Average Differential

A logit model was selected due to the binary characteristic of the dependent variable (e.g. whether or not project transition occurred). In lieu of the Flesh Readability Index, a related variable, the Flesch-Kinkaid Grade Level was leveraged. This transformation from readability to grade level provides for a more intuitive result. Performing the logit analysis in JMP yielded the following relation:

*Probability of Success = 1 / (1 + e^ (-8.078 + 0.68 * Flesch Kinkaid Grade Level)*

To provide more insight, the above function was leveraged to generate the probability of success as a function of grade level. As a point of reference, the average Flesch-Kinkaid Grade Level for the sustainment data set was between 15 and 16 (college junior to senior) and the success rate for that capability area was 7.9%.

FK Grade Level	Education Level	Probability of Project Success
12	High School Senior	48%
13	College Freshman	32%
14	College Sophomore	19%
15	College Junior	11%
16	College Senior	6%
17	First Year Grad Student	3%
18	Second Year Grad Student	0.016%
19	Higher Degree	0.008%
20	Higher Degree	0.004%

Table 5. Probability of Project Success for Given FK Grade Levels

The analysis indicates that a lower grade level (e.g. higher readability) has a correlation to project success. These results are for the maintenance topic area, a segment of the entire portfolio. The coefficient for the grade level has a negative coefficient (-0.6772) with a relatively low p-value (0.0608). This indicates that a lower grade level has a correlation to project success. When the analysis is expanded to the entire data set and includes all JCAs, the coefficient becomes positive (0.14677) and the p-value (0.0326) becomes statistically significant at an alpha of .05. Therefore, the behavior is reversed when the whole set is analyzed. Keep in mind that this initial look only accounts for the effect of readability on commercialization and does not include any additional variables.

Next, the entire data set was analyzed using all aforementioned independent variables. This analysis differs from previous analysis in that it considered JCA category as a variable. As a framing, the maintenance data is a sub-category of JCA 4 (e.g. it was a second level down, 4.4).

This whole set analysis considers the high level JCAs. The probability of commercialization was estimated by fitting a logistic regression model with a sample selection. The program "R Studio" was used for the logit model. The process is shown in appendix G. A summary of the results from this model are reported in the following table:

Variable	Coefficient	P - Value	Average Marginal Effect
FK_Grade	0.121164	0.0914*	0.0094
Woman_Owned	-0.327400	0.563	-0.0255
Number_Employees	-0.000714	0.760	-0.0001
Total_Awards	-0.004566	0.326	-0.0004
JCA_1	1.055896	0.247	0.0823
JCA_2	0.101916	0.836	0.0079
JCA_3	-0.383365	0.483	-0.0299
JCA_4	-0.871345	0.206	-0.0679
JCA_5	-14.250346	0.987	-1.1101
JCA_6	-0.299243	0.584	-0.0233
JCA_7	-0.063236	0.939	-0.0049

Table 6. Logistic Regression Model Results

FK_Grade is the only variable in the logit model for the probability of commercialization that enters significantly, although the positive effect does not support the hypothesis. This positive effect indicates that for every grade level the reading difficulty increases, the probability of commercialization increases 0.0094. This behavior in the full set represents a reversal of the

behavior observed in the maintenance data, where high readability (low grade level) correlated with higher success.

Future research needs to be conducted to investigate this relationship. It may be that the relationship is non-linear and a “sweet spot” exists for the readability of requirements. There may be other dynamics in this set that this level of analysis does not capture. Again, further research might look for higher order terms in the model.

Woman_Owned has a negative effect and does not enter significantly. The negative effect would indicate that if a SBIR topic is won by a woman-owned business, then the probability of commercialization on that project decreases by 0.0255. Yet, due to the p-value of 0.563, there is no statistical significance with this finding. The remaining variables, including contracts awarded and number of employees did not have significant p-values.

A separate analysis technique was leveraged to assess the effects of firm size (based on number of employees) and recidivism (based on total number of government contracts awarded). The scatter plot below (Figure 7) indicates that most of the successes in the set were present in the lower quarter (e.g. small company and few contracts), however, it is not clear that this is due to sampling bias or other effects.

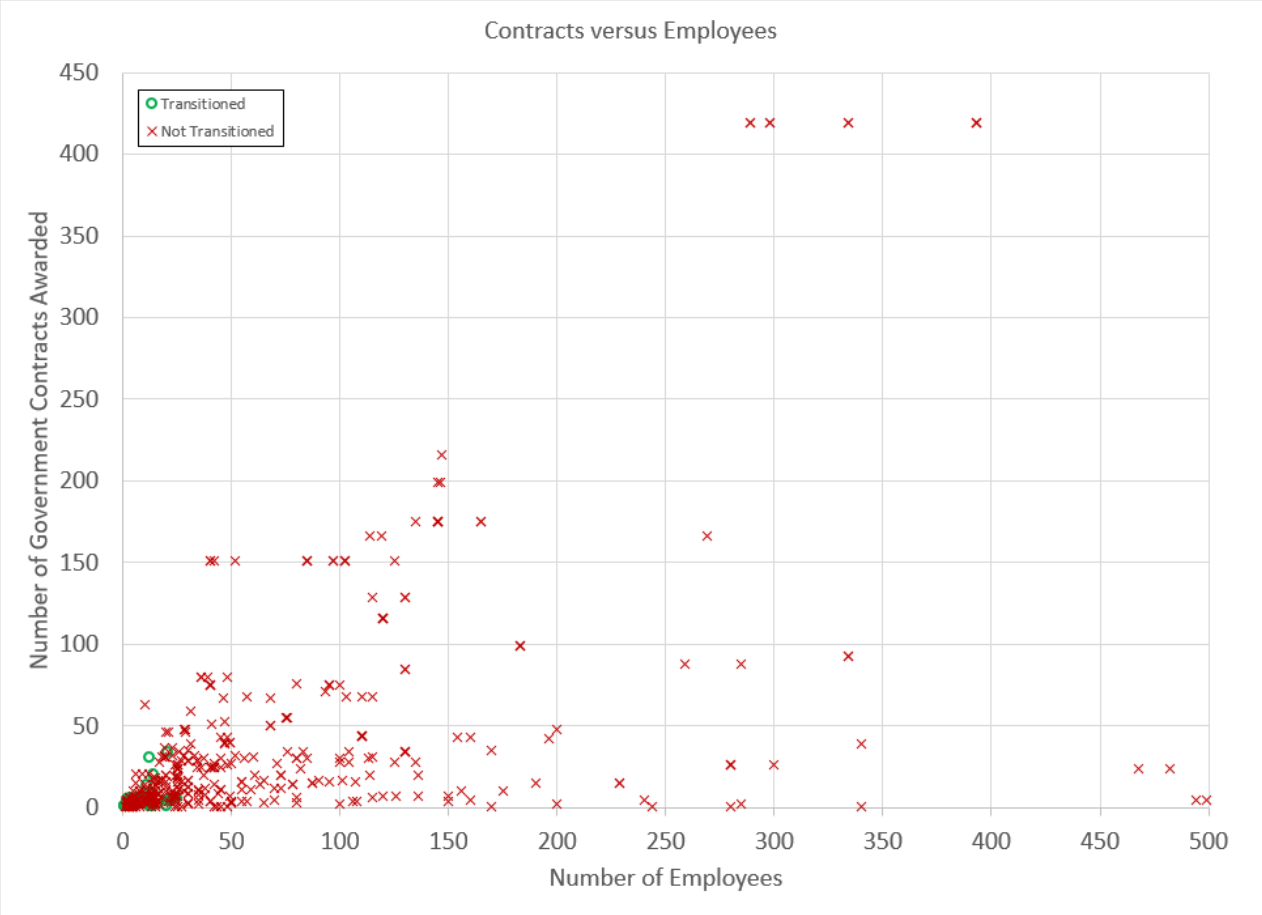


Figure 7. Contracts versus Employees

4.3 Bigger is Not Better

The current policy defines small businesses as those with 500 or fewer employees. As can be seen in the figure below there is a higher sample of smaller businesses in this set. The previous analysis attempted a fit for the data; this current analysis will compare the performance of larger companies to smaller companies to discern if there is a significant difference in performance.

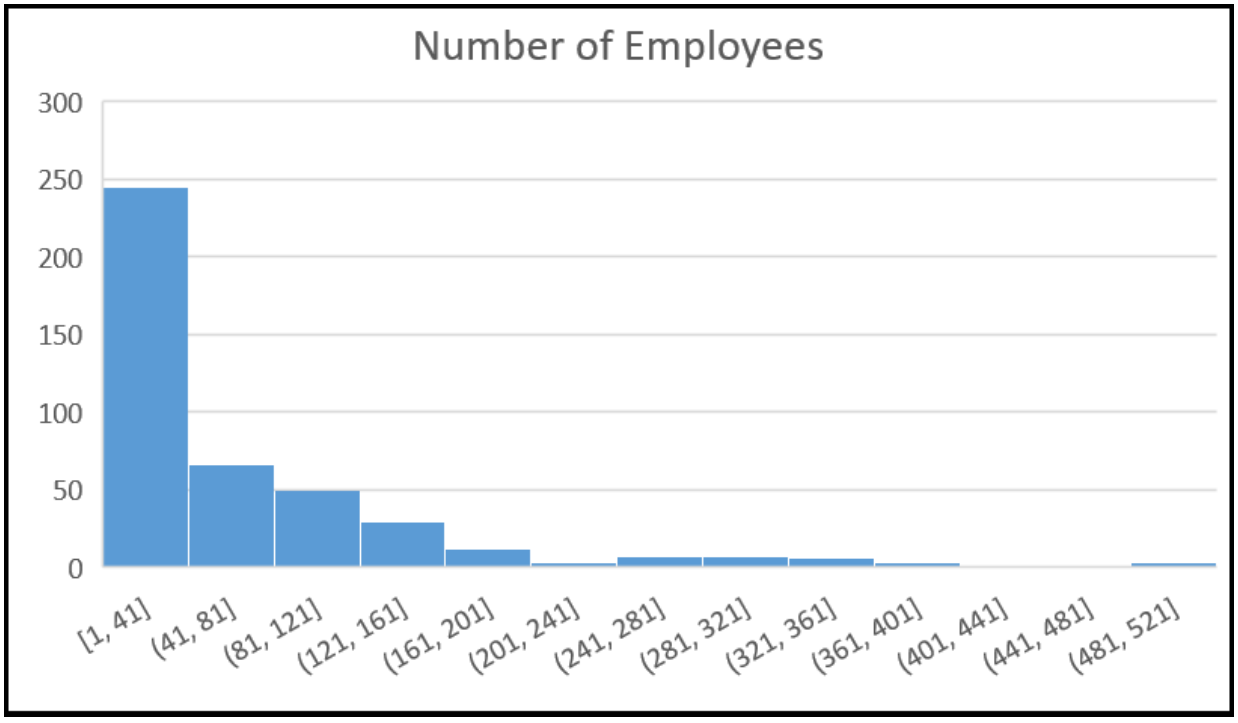


Figure 8. Histogram of Businesses by Size

The commercialization rate for businesses with 150 employees or fewer is 9% while the rate for businesses with greater than 150 employees is only 4%; the number 150 comes from the literature review, yet does not provide for a statistically viable comparison due to the numbers of successes and failures (Devore, 2014). To allow for a more robust comparison, the population of projects has been segmented based on size; where the lower quartile (companies with 1 to 14 employees) is compared to the upper quartile (from 96 to 500). The small companies had a performance of 9.4% whereas the larger companies had a transition performance of 8.4%. Statistical tests concerning population proportion were accomplished to compare these populations. It can be stated that the performance of these populations are different from one another with greater than 95% confidence (p value of .04) (Devore, 2014).

The data indicate that small companies yield higher transition rates by 1% as compared to large companies. While 1% may not seem high in the absolute, relative to the present performance

of 7.8%, an increase of 1% represents a 12.5% growth in performance. Future SBIR policy should consider favoring smaller businesses.

4.4 Stimulus versus Dependence

We next consider recidivism or the effect of the number of contracts awarded. Our population of companies had new entrants to government interaction up to companies with over 400 SBIR contracts awarded. A histogram of the companies based on population can be seen below. The number of contracts awarded was determined with X database and merged with this set based on the DUNS number, a characteristic number for any corporation that is much like a social security number. The average number of contracts awarded is 39.

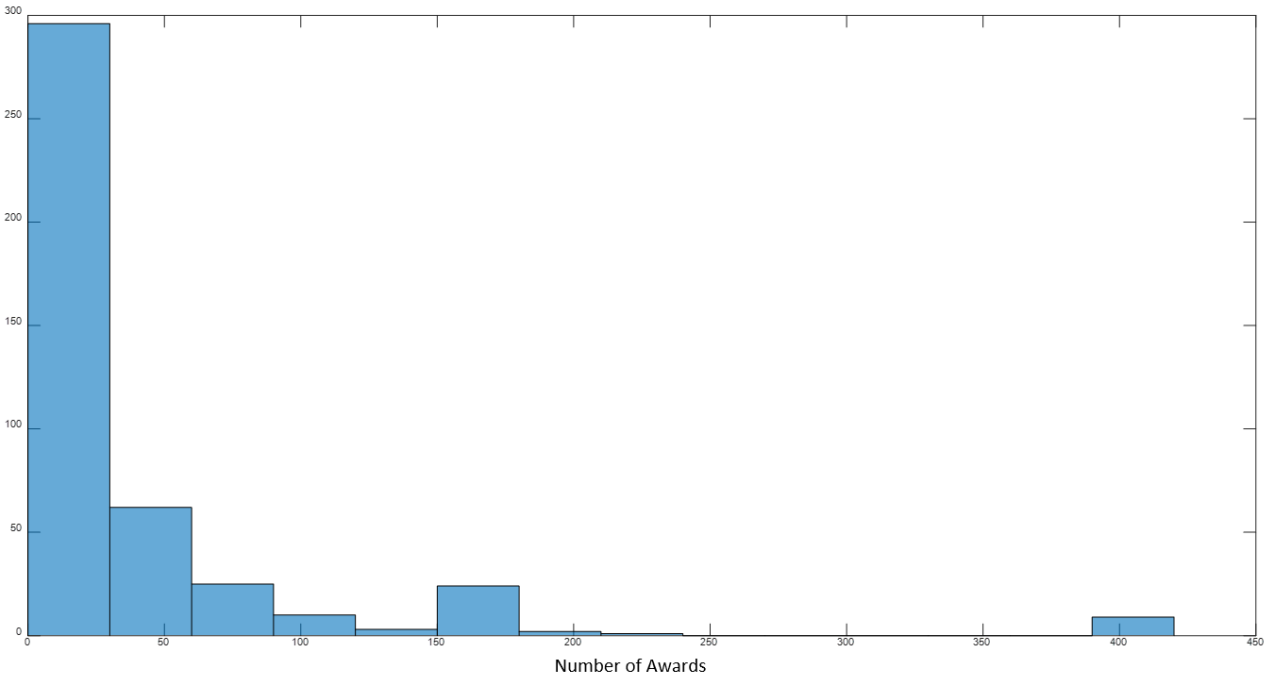


Figure 9. Histogram of Number of Contract Awards

Much like our previous analysis, the portfolio was segmented into quartiles and compared. The lower quartile ranged from 1 to 4 awards while the upper quartile ranged from 35 to 419 awards. The average success rates were 7.2% for the lower quartile and 7.4% for the upper quartile. While there is not a significant difference in performance between new and high repeat

firms, it was surprising to observe the degree of recidivism in this data set. If the intent of the SBIR program is the stimulus of small businesses at large, does the repeated stimulus of select companies meet the intent of the program. While there is no significant difference between new and high repeat firms, this can also be framed as there is no clear learning or improved performance as companies repeatedly interact with the government.

V. Conclusions and Recommendations

5.1 Chapter Overview

This research was motivated by calls for improved innovation from our National Defense Strategy and military leaders. The focus of this research is the performance of our existing Small Business Innovation Research Program and the determinants of success or commercialization. This research examined the impacts of factors that could affect the success of a SBIR project. The primary contribution of this research is a model to help determine which SBIR projects would be the most lucrative investments. Other contributions include corrections and additions to the data set. Readability statistics were calculated for the requirements of each topic and missing data was meticulously sought out and filled in. Future research is suggested to enhance and apply this framework to other areas of interest within the Air Force SBIR Program.

5.2 Conclusions of Research

The research analysis found that previous estimates for the commercialization rate of 7.6% were not correct, and the actual rate is 8.8%. Relevant to SBIR management policy, this research found that small businesses outperform larger companies. Additionally, readability statistics were calculated for the requirements of each SBIR project in the data set. For the maintenance and sustainability subset, it seems that readability correlates with success. However, there are other effects at play that result in a reversal of behavior for the larger set. In the logistic regression model, readability was found to have a significant impact of the commercialization rate, but the direction of the effect was the opposite of what was originally hypothesized. The results of this research analysis imply that the Small Business Innovation Research Program can best direct its investments by primarily working with smaller businesses.

5.3 Significance of Research

This research effort conducted an extensive commercialization analysis of SBIR contracts that represent over $182 million in SBIR funding. The results of this analysis provide decision makers with important information and tools that will enable them to direct investments with greater confidence. The implications of this analysis identify areas for process and policy improvements to better capitalize of commercializing innovative technologies. For example, perhaps the SBIR program should focus its investments on businesses with fewer employees. The direct effect of improvements such as these can be realized on an Air Force SBIR program that represents almost $1 billion in annual SBIR funding.

5.4 Limitations

There were several limitations noted during this research effort. The data set consists of only Air Force SBIR programs from Air Force Fiscal Years 2015 to 2018. SBIR programs within the data set that failed to include adequate cost or date data to determine Phase II contract closeout were excluded from analysis. Open SBIR Phase II contracts were excluded from analysis. Monetary commercialization dollars were the only examined success factor; the intrinsic value of diffused technology from SBIR efforts in the DoD or AF was not analyzed. The readability statistics used in this effort only account for average syllables per word and average words per sentence.

5.5 Investigative Questions Answered

The onset of this effort imposed several investigative questions towards the Air Force SBIR program. The successful conclusion of this research effort is obtained by comprehensively addressing each question. Extensive literature review and comprehensive analysis of Air Force

SBIR contracts was conducted to provide insight that will answer those questions. The answers consist of summarized findings stated in this chapter or previous chapters.

What behaviors or patterns exist among successful Air Force SBIR projects?

The total commercialization rate of closed Air Force SBIR contracts within the Air Force SBIR program from Fiscal Year 2015 to Fiscal Year 2018 was 8.8%. For the overall data set, the patterns that exist among successful Air Force SBIR projects include:

1) Businesses that have 150 employees or fewer
2) Force Integration, Battlespace Awareness, & Protection (top performers)
3) Requirements written at a high grade level (interestingly)

What behaviors or patterns exist among unsuccessful Air Force SBIR projects?

For the overall data set, the patterns that exist among unsuccessful Air Force SBIR projects include:

1) Businesses that approach the 500 employee limit (except "SBIR mills")
2) Command/Control, Logistics, Force Application (worst performers)
3) Requirements written at a lower grade level

What methods can be developed to investigate and explain those behaviors and patterns?

This effort utilized a DoD JCA taxonomy which provides the best appropriate categorical method to identify and compare commercialization rates among capability areas. Assignment by a panel of raters was the best method to assign JCAs to a SBIR topic, resulting in over 97.4% agreement across the SBIR topics assigned (Rask, 2019). A logistic regression model was used to determine the average marginal effect that each variable would have on the probability of commercialization for a given product.

How do patterns differ when projects are homogenous versus heterogeneous?

Analysis of the data set as a whole (heterogeneous) showed that readability has an overall positive effect of commercialization. However, when analysis was focused on the maintenance and sustainability portion of the data (homogenous), readability seems to have a negative effect. Further research is needed to examine third level JCAs independently and perhaps investigate higher order terms in the logit model.

What recommendations can be made to improve the success rate of AF SBIR projects?

The Air Force SBIR program should focus investments on projects that exhibit the behaviors or patterns of successful topics shown in the first research question. In short, the program should focus investments on projects with businesses of 150 or fewer people and JCAs of Force Integration, Battlespace Awareness, and Protection.

5.6 Recommendations for Future Research

Future research recommendations include expanding analysis on the current data set and conducting additional analysis on related data. As this research effort has done, future researchers would be able to add variables to the data set to conduct research from a new or different perspective. Additionally, the logistic regression methods used in this effort could be applied to third level JCAs to get a stronger look at homogenous data. Finally, the use of higher order terms in the logit model could be explored to look for relationships that are non-linear.

5.7 Summary

As this analysis shows, the Air Force SBIR Program has seen a high rate of failure, over 91%, in Phase II efforts that have completed funding within the last three Fiscal Years. The JCA assignment process and subsequent analysis identified several high and low performing groups. Force Integration, Battlespace Awareness, and Protection JCAs were top performers while

Command/Control, Logistics, and Force Application were low performers. Additional analysis showed that small businesses have more than double the commercialization rate of large businesses. The commercialization rates for businesses with 150 employees or fewer is 9% while the rate for businesses with greater than 150 employees is only 4%.

Readability statistics were calculated for the requirements of each SBIR project in the data set. For the maintenance and sustainability subset, it seems that readability correlates with success. However, there are other effects at play that result in a reversal of behavior for the larger set. In the logistic regression model, readability was found to have a significant impact of the commercialization rate, but the direction of the effect was the opposite of what was originally hypothesized.

These findings provide the Air Force SBIR Program focus areas to concentrate funding or attention, to improve the commercialization rate, and to ultimately improve the return on investment for a program that utilizes almost $1 billion in annual DoD funding.

Appendix A. Joint Capability Area Definitions

JOINT CAPABILITY AREA DEFINITIONS

Table of Contents

1. **Force Integration** – The ability to establish, develop, and maintain a mission ready Joint Force and build relationships with foreign and domestic partners.

1.1. **Force Management** – The ability to integrate new and existing human and technical assets from across the Joint Force and its mission partners to provide capabilities in support of global operations.

1.1.1. **Global Force Management** – The ability to align force apportionment, assignment, and allocation of forces to combatant commanders in support of the National Defense Strategy and joint force availability requirements

1.1.2. **Force Configuration** – The ability to translate doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTmLPF-P) requirements into programs and structure.

1.1.3. **Global Defense Posture Execution** – The ability to develop a global network of host-nation relationships, activities, and footprint of facilities and forces by refining operational requirements for, implementing, and sustaining posture changes.

1.1.4. **Readiness Reporting** – The ability to evaluate, appraise, and characterize the status of military capabilities (including force structure, modernization, unit readiness, and sustainability), joint readiness, and the supporting infrastructure to perform assigned missions.

1.1.5. **Human Capital Management** – The ability to ensure and support, within the life cycle management of total force human resources, the availability of personnel equipped with skill sets required for mission success.

1.2. **Force Preparation** – The ability to develop, enhance, and adapt the Joint Force, complemented by Allies and Partners for unified action.

1.2.1. **Training** – The ability to instruct and apply exercises for acquiring and retaining skills, knowledge, and abilities required to perform specific tasks.

1.2.2. **Exercising** – The ability to conduct military maneuver or simulate wartime operations involving planning, preparation, and execution that is carried out for the purpose of training and evaluation.

1.2.3. **Education** – The ability to convey general bodies of knowledge and develop habits of mind applicable to a broad spectrum of endeavors to foster breadth of view, diverse perspectives, critical analysis, and abstract reasoning.

1.2.4. **Doctrine** – The ability to provide fundamental principles that guide the employment of military forces in coordinated action toward a common objective and serves to make US policy and strategy effective in the application of military power.

1.2.5. **Lessons Learned** – The ability to identify, collect, analyze, validate, disseminate, and operationalize a lesson that contributes to improved performance or increased capability through documentation of lessons and best practices across DOTmLPF-P.

1.2.6. **Concepts** – The ability to examine challenges and opportunities of the future operational environment and identify potential alternate methods of operating and potential required capabilities.

1.2.7. **Experimentation** – The ability to conduct analytic activities derived from unbiased trials conducted under controlled conditions within a representative environment in order to help solve joint challenges/problems/issues.

1.3. **Building Partnerships** – The ability to conduct activities and engage with foreign and domestic partner leaders, security and other government institutions, nongovernmental organizations, and relevant populations to build defense relationships through formal and informal agreements to achieve shared objectives.

1.3.1. **Engage Partners** – The ability to integrate and synchronize interactions with foreign and domestic governments and institutions to facilitate the development of formal or informal partnerships.

1.3.2. **Manage Partnership Agreements** – The ability to develop, maintain, and disestablish partnerships.

1.3.3. **Conduct Security Cooperation Activities** – The ability to assess, monitor, evaluate, sustain, develop, and leverage the military, security, or other capabilities and capacities of partners.

1.3.4. **Conduct Civil-Military Operations** – The ability to establish and maintain relations between military forces, indigenous populations, and institutions by directly support the attainment of objectives relating to stability within a region or host nation.

2. **Battlespace Awareness (BA)** – The ability to understand dispositions and intentions as well as the characteristics and conditions of the operational environment that bear on national and military decision making by leveraging all sources of information to include Intelligence, Surveillance, Reconnaissance, Meteorological, and Oceanographic.

2.1. **Planning & Direction** – The ability to synchronize and integrate the activities of collection, processing, exploitation, analysis and dissemination resources to satisfy intelligence requirements.

2.1.1. **Define & Prioritize Requirements** – The ability to translate national through tactical objectives and needs into intelligence requirements, information requirements, and specific information requirements.

2.1.2. **Develop Plans & Strategies** – The ability to determine and document in plans the best approach to collect, process, exploit, analyze, and disseminate data, information, and intelligence to address requirements and maintain estimates of likely outcomes.

2.1.3. **Task & Monitor Resources** – The ability to task, track, direct, assess, and adjust intelligence operations and their associated resources to fulfill requirements.

2.2. **Collection** – The ability to gather data to satisfy information needs.

2.2.1. **Signals Collection** – The ability to gather information based on the interception of electromagnetic impulses.

2.2.1.1. **Communications (SC)** – The ability to intercept and derive information from voice and data communications.

2.2.1.2. **Electronic Emissions (SC)** – The ability to intercept and derive information from non-communication transmissions.

2.2.1.3. **Foreign Instrumentation (SC)** – The ability to intercept data from foreign equipment and control systems.

2.2.1.4. **Cyberspace Networks (SC)** – The ability to access and gather data from automated information systems, networks, and databases.

2.2.2. **Imagery Collection** – The ability to obtain a visual presentation or likeness of any natural or man-made feature, object, or activity at rest or in motion.

2.2.2.1. **Electro-Optical (IC)** – The ability to obtain a visual presentation of any natural or man-made feature, object, or activity derived from the ultraviolet through far infrared electromagnetic spectrum.

2.2.2.2. **Light Detection & Ranging (IC)** – The ability to obtain a visual presentation produced by recording pulsed laser light reflected from a given object.

2.2.2.3. **Radar (IC)** – The ability to obtain a visual presentation produced by recording radar waves from any natural or man-made feature, object, or activity.

2.2.2.4. **Sonar (IC)** – The ability to measure and characterize surfaces, natural or man-made objects, and layers of the maritime and littoral features.

2.2.2.5. **Physical Environment (IC)** – The ability to sense or acquire meteorological, oceanographic, and space environmental data through measurement, monitoring, and sensor observations.

2.2.3. **Measurement & Signature Collection** – The ability to gather parameters and distinctive characteristics of natural or man-made phenomena, equipment, or objects.

2.2.3.1. **Electro-Optical (MSC)** – The ability to collect information on phenomena that emit, absorb, or reflect electromagnetic energy in the ultraviolet through infrared spectrum.

2.2.3.2. **Radar (MSC)** – The ability to actively or passively collect energy reflected from any natural or man-made feature, object, or activity.

2.2.3.3. **Geophysical (MSC)** – The ability to detect phenomena and gather information transmitted through the geophysical area of the earth, oceans, and surrounding atmosphere, including man-made objects.

2.2.3.4. **Radio-Frequency (MSC)** – The ability to collect information from radiation transmissions and electromagnetic pulses.

2.2.3.5. **Materials (MSC)** – The ability to gather information from chemical and biological agents, objects, and activities.

2.2.3.6. **Nuclear Radiation (MSC)** – The ability to obtain information derived from nuclear radiation and other physical phenomena associated with nuclear weapons, reactors, devices, facilities, and fissile materials.

2.2.3.7. **Sonar (MSC)** – The ability to measure and characterize surfaces, natural or man-made objects, and layers of the maritime and littoral environment.

2.2.3.8. **Physical Environment (MSC)** – The ability to sense or acquire meteorological, oceanographic, and space environmental data through measurement, monitoring, and sensor observations.

2.2.3.9. **Biometrics Data (MSC)** – The ability to gather measurable anatomical, physiological, and behavioral characteristics of an individual.

2.2.4. **Human-based Collection (HBC)** – The ability to acquire information from human resources, human-derived data, or human reconnaissance and surveillance assets.

2.2.4.1. **Human Intelligence (HBC)** – The ability to gather information for intelligence purposes from human sources.

2.2.4.2. **Counterintelligence Collection** – The ability to gather information to identify threats posed by foreign governments and organizations, foreign persons, or international terrorists.

2.2.4.3. **Observation** – The ability to use human resources to obtain, by visual observation and other detection methods, information about the physical environment and surrounding activities.

2.2.4.4. **Documents, Media, & Materiel** – The ability to obtain through battlefield seizure or other means, documents electronic media, and foreign materiel.

2.2.4.5. **Social-Cultural Data** – The ability of human resources applying their knowledge of a language, culture, or region to obtain social or cultural information about the operational environment from the individual to the national level.

2.2.5. **Open Source Collection** – The ability to acquire information from publicly available documents and electronic media.

2.3. **Processing & Exploitation** – The ability to convert collected information into forms suitable for further analysis and/or action.

2.3.1. **Processing** – The ability to convert raw data into forms suitable for exploitation.

2.3.1.1. **Signals Data Processing** – The ability to convert raw data from electromagnetic impulses into forms suitable for exploitation.

2.3.1.2. **Imagery Data Processing** – The ability to convert raw data representing natural or man-made features, objects, or activities at rest or in motion into forms suitable for exploitation.

2.3.1.3. **Measurement & Signature Data Processing** – The ability to convert raw data associated with parameters and distinctive characteristics of natural or man-made phenomena, equipment, or objects into forms suitable for exploitation.

2.3.1.4. **Human-acquired Data, Media, & Materiel Processing** – The ability to convert raw data, documents, electronic media, or foreign materiel gathered from or seized by human sources into forms suitable for exploitation.

2.3.1.5. **Open-sourced Data Processing** – The ability to convert raw data obtained from publicly available documents and electronic media into forms suitable for exploitation.

2.3.2. **Exploitation** – The ability to transform processed data into information for immediate use or for additional analysis in the production of intelligence.

2.3.2.1. **Signals Data Exploitation** – The ability to select and transform raw signals data into intelligible information for immediate use or further analysis.

2.3.2.2. **Imagery Data Exploitation** – The ability to select and transform processed imagery data into intelligible information for immediate use or further analysis.

2.3.2.3. **Measurement & Signature Data Exploitation** – The ability to select and transform processed measurement and signature data into intelligible information for immediate use or further analysis.

2.3.2.4. **Human-acquired Data, Media, & Materiel Exploitation** – The ability to select and transform raw data, media, or materiel gathered from or seized by human sources into intelligible information for immediate use or further analysis.

2.3.2.5. **Open-Sourced Data Exploitation** – The ability to select and transform data gathered from publicly available sources into intelligible information for immediate use or analysis.

2.3.3. **Report Generation** – The ability to document the results of processing and exploitation in text, graphic, or other forms for subsequent dissemination to intelligence analysts or other consumers.

2.3.3.1. **Signals Intelligence Report Generation** – The ability document the results of signals data exploitation in text, graphic, or other forms.

2.3.3.2. **Imagery Intelligence Report Generation** – The ability to document the results of imagery data exploitation in text, graphic, or other forms.

2.3.3.3. **Geospatial Intelligence Report Generation** – The ability to document the results of geographically-referenced imagery intelligence in text, graphic, or other forms.

2.3.3.4. **Measurement & Signature Intelligence Report Generation** – The ability to document the results of measurement and signature data exploitation in text, graphic, or other forms.

2.3.3.5. **Counterintelligence Report Generation** – The ability to document the exploitation of information regarding threats posed by foreign governments and organizations, foreign persons, or international terrorists in text, graphic, or other forms.

2.3.3.6. **Human Intelligence Report Generation** – The ability to document the exploitation of information gathered from human sources in text, graphic, or other forms.

2.3.3.7. **Documents & Media Report Generation** – The ability to document information derived from the exploitation of seized or publically available documents and electronic media in text, graphic, or other forms.

2.3.3.8. **Technical Intelligence Report Generation** – The ability to document information derived from the exploitation of foreign materiel in text, graphic, or other forms.

2.4. **Analysis, Estimation, & Production** – The ability to integrate, evaluate, analyze, and interpret information from all available sources to develop intelligence that enables situational awareness of the current state of the operational environment (OE) and an understanding of the relative probability of alternative future conditions of the OE and adversary activity.

2.4.1. **Integration** – The ability to identify, assimilate and correlate relevant information from single or multiple sources.

2.4.2. **Evaluation** – The ability to provide focused examination of the information and assess its reliability and credibility to a stated degree of confidence.

2.4.3. **Interpretation** – The ability to derive knowledge and develop new insight from gathered information to postulate its significance.

2.4.4. **Estimation** – The ability to determine the relative order of probability of alternative future conditions of the OE and adversary activity.

2.4.5. **Product Generation** – The ability to document intelligence in text, graphic, and other forms.

2.4.5.1. **Warning Intelligence Product Generation** – The ability to document intelligence assessments relating to time-sensitive threats against US security, interests, or citizens.

2.4.5.2. **Current Intelligence Product Generation** – The ability to document intelligence assessments needed to support on-going military operations through concise, objective assessments of the current situation in a particular area.

2.4.5.3. **General Military Intelligence Product Generation** – The ability to document intelligence assessments on the military capabilities of foreign countries and organizations, to include non-state actors, and other topics that could affect potential US or multinational military operations.

2.4.5.4. **Target Intelligence Product Generation** – The ability to document intelligence assessments that portray, characterize, and locate the components of a target or target complex, networks, and support infrastructure, and to indicate their vulnerability and relative importance to the adversary.

2.4.5.5. **Scientific & Technical Intelligence Product Generation** – The ability to document intelligence assessments on foreign developments in basic and applied sciences and technologies with warfare potential and, in particular, enhancements to foreign weapon systems.

2.4.5.6. **Counterintelligence Product Generation** – The ability to document intelligence assessments on threats to the Department of Defense (DoD) posed by foreign intelligence entities.

2.4.5.7. **Identity Intelligence Production Generation** – The ability to document the fusion of a variety of identity attributes (biological, biographic, behavioral, and reputational information related to individuals) to reveal the existence of previously unknown individual actors who may pose threats to US interests.

2.4.5.8. **Estimative Intelligence Product Generation** – The ability to document intelligence estimates that forecast in relative order of probability the full range of alternative situations and adversary courses of action with implications for planning and executing military operations.

2.5. **BA Dissemination & Integration** – The ability to transmit, distribute, present, or make available collected data, information reports, or intelligence products.

2.5.1. **BA Data Transmission** – The ability to send collected data directly to processing, exploitation analysis, production and visualization systems, leveraging both Department of Defense Information Network (DODIN) and intelligence-controlled systems.

2.5.2. **BA Data Access** – The ability to provide authorized customer access to data and products, leveraging both DODIN and intelligence-controlled systems.

2.6. **Counterintelligence (CI)** – The ability to identify, deceive, exploit, disrupt, or protect against espionage, other intelligence activities, sabotage, or assassinations conducted by or on behalf of foreign powers, organizations, or persons, or by international terrorist organizations or activities.

2.6.1. **Offensive CI** – The ability to develop information on and provide information, materials, or equipment to a Foreign Intelligence Entity (FIE) for the purpose of penetrating the FIE, or exploiting, disrupting, or manipulating the FIE target.

2.6.2. **Investigations** – The ability to determine whether a person is acting on behalf of, or an event is related to, a foreign power engaged in spying or committing espionage, sabotage, treason, sedition, subversion, assassinations, or international terrorist activities, and to determine actions required to neutralize such acts.

3. **Force Application** – The ability to integrate maneuver and kinetic, electromagnetic, and informational fires to gain a position of advantage and/or create lethal or nonlethal effects on designated targets.

3.1. **Maneuver** – The ability to move to a position of advantage.

3.1.1. **Air** – The ability to move to a position of advantage in the air domain.

3.1.2. **Space** – The ability to move to a position of advantage in the space domain.

3.1.3. **Land** – The ability to move to a position of advantage in the land domain.

3.1.4. **Maritime** – The ability to move to a position of advantage in the maritime domain, excluding the air space above the maritime domain.

3.1.5. **Cyberspace** – The ability to move to a position of advantage in the cyberspace domain.

3.1.6. **Electromagnetic Spectrum** – The ability to move to a position of advantage within the electromagnetic spectrum.

3.2. **Fires** – The ability to create lethal and/or nonlethal effects on designated targets.

3.2.1. **Kinetic** – The ability to create lethal or nonlethal effects on designated targets in the air, land, space, and maritime domains.

3.2.2. **Electromagnetic** – The ability to create lethal or nonlethal effects on designated targets with electromagnetic energy.

3.2.3. **Information** – The ability to create effects on humans and automated systems in the information environment.

3.2.3.1. **Inform** – The ability to communicate accurate information to domestic, international, and internal audiences.

3.2.3.2. **Influence** – The ability to affect the factors that drive the behavior of foreign individuals, groups, and populations.

3.2.3.3. **Cyberspace** – The ability to manipulate or degrade, disrupt, or destroy designated targets in and through cyberspace, external to the DODIN.

4. **Logistics** – The ability to project and sustain the Joint Force.

4.1. **Deployment & Distribution** – The ability to strategically and operationally move forces and sustainment in support of military operations.

4.1.1. **Force Deployment** – The ability to transport units, equipment and initial sustainment from the point of origin to the point of need.

4.1.2. **Force Sustainment** – The ability to deliver supplies, equipment, and personnel replacements to the joint force.

4.2. **Supply** – The ability to identify and select supply sources, schedule deliveries, receive, verify, and transfer product and authorize supplier payments. This includes the ability to see and manage inventory levels, capital assets, domestic business rules, supplier networks and agreements (to include import requirements) as well as assessment of supplier performance.

4.2.1. **Supplies & Equipment Management** – The ability to maintain accountability, store, preserve, and set stockage levels of materiel and equipment.

4.2.2. **Inventory Management** – The ability to receive materiel in the right quality and quantity and to enable precise distribution and transfer of materiel to the customer while integrating and optimizing the links or business processes between supply nodes, maintenance, and distribution providers.

4.2.3. **Global Supplier Networks Management** – The ability to source routine and surge requirements from the U.S. industrial base, ensure global supply availability and the capacity to support operations involving U.S., IA, PVO, and MN partners engaged in ever changing military activities around the globe.

4.3. **Maintenance (Depot & Field)** – The ability to manufacture and retain materiel in a serviceable condition or restore materiel to a serviceable condition.

4.3.1. **Inspect** – The ability to determine faults or verify repairs or determine condition of an item of equipment based on established equipment maintenance and serviceability standards.

4.3.2. **Test** – The ability to evaluate the operational condition of an end item or subsystem thereof against an established standard or performance parameter.

4.3.3. **Service** – The ability to conduct preventive maintenance checks and scheduled maintenance to detect, correct or prevent minor faults before these faults cause serious damage, failure, or injury.

4.3.4. **Repair** – The ability to restore an item to serviceable condition through correction of a specific failure or condition.

4.3.5. **Rebuild** – The ability to recapitalize an item to a standard as nearly as possible to its original condition in appearance, performance, and life expectancy.

4.3.6. **Calibrate** – The ability to compare an instrument with an unverified accuracy to an instrument of known or greater accuracy to detect and correct any discrepancy in the accuracy of the unverified instrument.

4.3.7. **Reclaim** – The ability to retain and/or demilitarize authorized end items, assemblies, and sub-assemblies prior to disposal.

4.4. **Logistics Services** – The ability to provide services and functions essential to the technical management and support of the joint force.

4.4.1. **Food Services** – The ability to plan, synchronize and manage subsistence support to the joint force to include dining facility management, subsistence procurement and storage, food preparation, field feeding and nutrition awareness.

4.4.2. **Water & Ice Services** – The ability to produce, test, store and distribute bulk, packaged and frozen water in a contingency environment.

4.4.3. **Contingency Base Services** – The ability to provide shelter, billeting, waste management and common user life support management in a contingency environment.

4.4.4. **Hygiene Services** – The ability to provide laundry, shower, textile and fabric repair support.

4.4.5. **Mortuary Affairs** – The ability to conduct contingency fatality operations, and conduct mortuary operations for the remains of persons and personal effects for whom DoD Components are responsible by policy and statute.

4.5. **Operational Contract Support** – The ability to plan for and obtain supplies, services, and construction from commercial sources in support of joint operations along with the associated contract support, integration, contracting support, and management functions.

4.5.1. **Contract Support Integration** – The ability to provide coordinated and synchronized contracted support being executed in a designated operational area in support of the Joint Force.

4.5.2. **Contractor Management** – The ability to oversee and integrate contractor personnel and associated equipment providing support to the Joint Force in a designated operational area.

4.6. **Engineering** – The ability to execute and integrate combat, general, and geospatial engineering to meet national and JFC requirements to assure mobility, provide infrastructure to position, project, protect, and sustain the joint force, and enhance visualization of the operational area, across the full spectrum of military operations.

4.6.1. **General Engineering** – The ability to employ engineering capabilities and activities, other than combat engineering, that provide infrastructure and modify, maintain, or protect the physical environment. Examples include: the construction, repair, maintenance, and operation of infrastructure, facilities, lines of communication and bases; terrain modification and repair; and selected explosive hazard activities.

4.6.1.1. **Gap Crossing** – The ability to enable joint forces to overcome breaks or openings in terrain (dry or wet, natural or man-made).

4.6.1.2. **Develop & Maintain Facilities** – The ability to develop, rehabilitate, and maintain facilities and infrastructure by providing design, real estate, construction, and environmental services which extend through final disposition.

4.6.1.3. **Establish Lines of Communication** – the ability to assess, construct, repair, and improve routes, railroads, intermodal facilities, and supporting infrastructure to allow the speedy flow of personnel, supplies, and equipment into theater and forward to tactical units.

4.6.1.4. **Global Access Engineering** – The ability to enable theater access by determining and documenting infrastructure capacities, in-situ soils, hydrology, and environmental conditions, and forecast and mitigate limitations to enable deployment and improve throughput capacities.

4.6.1.5. **Repair & Restore Infrastructure** – The ability to rehabilitate critical infrastructure. This capability includes repairing or demolishing damaged buildings, restoring utilities such as electrical power, and bringing critical facilities such as hospitals, water treatment plants and waste management facilities online.

4.6.1.6. **Harden Key Infrastructure & Facilities** – The ability to apply site- and threat-adaptable plans and designs, advanced construction techniques and materials in order to enhance the prevention or mitigation of hostile actions against materiel resources, facilities and infrastructure.

4.6.1.7. **Master Facility Design** – The ability to integrate land use, bills of material and forecasts, and construction requirements that facilitate project execution and developing infrastructure and facilities.

4.6.2. **Combat Engineering** – The ability to employ engineering capabilities and activities that support the maneuver of land combat forces and that require close support to those forces. Combat engineering consists of three types of capabilities and activities: mobility, counter-mobility, and survivability.

4.6.2.1. **Defeat Explosive Hazards** – The ability to locate and neutralize the full range of enemy and friendly explosive hazards that may impede routine operations, decrease mobility or present a threat to force protection. It includes the capability to locate, avoid, and neutralize hazards in concert with mounted or dismounted maneuver (breach) or as part of tactical/operational movement (route clearance).

4.6.2.2. **Enhance Mobility** – The ability to enable both mounted and dismounted movement and maneuver where and when desired without interruption or delay through complex terrain (ranging from littoral to mountainous areas), built up areas (cities, towns, and villages to include subterranean structures), and complex manmade and natural obstacles to achieve the commander's intent without loss of speed or flexibility.

4.6.2.3. **Deny Movement & Maneuver** – The ability to enable the Joint Force Commander to quickly dominate terrain and modify the physical environment in order to isolate forces, deny key terrain and impede, deny or canalize movement via lethal and nonlethal means.

4.6.2.4. **Enhance Survivability** – The ability to provide coordinated and synchronized engineer support (including camouflage techniques) and construction to increase force protection and conserve the Joint Force's fighting capabilities and freedom of action.

4.6.3. **Geospatial Engineering** – The ability to portray and refine data pertaining to the geographic location and characteristics of natural or constructed features and boundaries in order to provide engineer services. Examples include: terrain analyses, terrain visualization, digitized terrain products, nonstandard tailored map products, facility support, and force bed-down analysis.

4.6.3.1. **Utilize Geospatial Data** – The ability to provide the Joint Force Commander with the foundation layer of the operational environment for use with collaborative decision-support, and terrain analysis tools.

4.6.3.2. **Provide Mobility Assessments** – The ability to understand a planned area of operations through the development of assessments on aerial and sea ports, transportation networks, cross country mobility, and mobility corridors.

4.7. **Base & Installation Support** – The ability to provide enduring bases and installations with the assets, programs, and services necessary to support US military forces.

4.7.1. **Real Property Life Cycle Management** – The ability to acquire, operate, sustain, recapitalize, realign, and dispose of real property assets to meet the requirements of the force.

4.7.2. **Installation Services** – The ability to deliver selected services not related to real property or personnel services to meet the requirements of the installation population and mission, to include emergency services, installation safety, base support vehicles and equipment, housing services, airfield management, port services, range management, launch support services, and installation feeding.

4.8. **Health Services** – The ability to perform, provide, or arrange the promotion, improvement, conservation, or restoration of human mental and physical well-being.

4.8.1. **Operational Medicine** – The ability to sustain and protect the health and effectiveness of the Joint Force and provide safe and effective movement of ill and injured personnel to higher levels of care within and outside the Joint Operational Area. This includes the ability to provide for a healthy, fit, and protected force; engage in health surveillance; and manage casualties in a Joint Operational area; and safeguard the health of detained personnel.

4.8.2. **Health Services Delivery** – The ability to provide acute or long-term primary or specialty care to the Joint Force outside of Joint Operational Areas in either the direct or contracted care system and build healthy communities by managing and delivering the health benefit. This ability includes clinical preventive medicine, clinical diagnostics, treatment, rehabilitation, and regeneration.

5. **Command & Control** – The ability to exercise authority and direction by a properly designated commander or decision maker over assigned and attached forces and resources in the accomplishment of the mission.

5.1. **Organize** – The ability to align or synchronize interdependent and disparate entities, including their associated processes and capabilities to achieve unity of effort.

5.1.1. **Establish & Maintain Unity of Effort with Mission Partners** – The ability to foster and maintain cooperative relations with mission partners.

5.1.2. **Structure Organization to Mission** – The ability to dynamically organize elements and define roles, responsibilities, and authorities.

5.1.3. **Foster Organizational Collaboration** – The ability to establish internal structures and processes and external interfaces that facilitate interaction and coordination.

5.2. **Understand** – The ability to individually and collectively comprehend the implications of the character, nature, or subtleties of information about the operational environment and situation.

5.2.1. **Organize Information** – The ability to discover, select, and distill information within an established context.

5.2.2. **Develop Knowledge & Situational Awareness** – The ability to apply context, experience, and intuition to data and information to derive meaning and value.

5.2.3. **Share Knowledge & Situational Awareness** – The ability to communicate synthesized information and context.

5.3. **Plan** – The ability to establish a framework to employ resources to achieve a desired outcome or effect.

5.3.1. **Analyze Problem** – The ability to review and examine all available information to determine necessary actions.

5.3.2. **Apply Situational Understanding** – The ability to use synthesized information and awareness applicable to a given situation or environment to further understand the problem.

5.3.3. **Develop Strategy** – The ability to create a framework that synchronizes and integrates the resources available to achieve a desired outcome or effect.

5.3.4. **Develop Courses of Action** – The ability to determine and refine sequences of activities to achieve a desired outcome or effect.

5.3.5. **Analyze Courses of Action** – The ability to evaluate potential solutions to determine likelihood of success.

5.4. **Decide** – The ability to select a course of action informed and influenced by the understanding of the environment or a given situation.

5.4.1. **Manage Risk** – The ability to recognize and balance the likelihood and consequences of undesired effects with the desired outcomes/effects.

5.4.2. **Select Actions** – The ability to choose a prudent idea or set of ideas that leads to a desired outcome or end-state within a defined set of constraints.

5.4.3. **Establish Rule Sets** – The ability to construct directives that delineate circumstances and limitations for actions.

5.4.4. **Establish Intent & Guidance** – The ability to formulate a concise expression of purpose, methods, acceptable risk, and desired end-state.

5.5. **Direct** – The ability to employ resources to achieve an objective.

5.5.1. **Communicate Intent & Guidance** – The ability to promulgate a concise expression of the operational purpose, assessment of acceptable operational risk, and guidance to achieve the desired end-state.

5.5.2. **Task** – The ability to direct actions and resources.

5.5.3. **Establish Metrics** – The ability to establish objective criteria to assess performance and results.

5.6. **Monitor** – The ability to adequately observe and assess events/effects of a decision.

5.6.1. **Assess Compliance with Guidance** – The ability to determine if performance adheres to established parameters and expectations.

5.6.2. **Assess Effects** – The ability to analyze, track, and measure the results of actions taken.

5.6.3. **Assess Achievement of Objectives** – The ability to determine when the desired end-state has been reached.

5.6.4. **Assess Guidance** – The ability to determine if direction is achieving the desired end-state and is appropriate for the situation.

6. **Communications & Computers** – The ability to share and protect information across DoD and with partners.

6.1. **Information Transport** – The ability to transport information and services via assured end-to-end connectivity.

6.1.1. **Wired Transmission** – The ability to transfer data or information with an electrical/optical conductor.

6.1.2. **Wireless Transmission** – The ability to transfer data or information without an electrical/optical conductor.

6.1.3. **Switching & Routing** – The ability to move data and information end-to-end across multiple transmission media.

6.2. **Network Management** – The ability to configure and re-configure networks, services and the underlying physical assets that provide end-user services, as well as connectivity to enterprise application services.

6.2.1. **Optimized Network Functions & Resources** – The ability to provide DoD with responsive network functionality and dynamically configurable resources, to include allocation of required bandwidth, computing and storage.

6.2.2. **Deployable, Scalable, & Modular Networks** – The ability to design, assemble, transport, and establish mission-scaled networks from adaptable components network modules.

6.2.3. **Spectrum Management** – The ability to synchronize, coordinate, and manage all elements of the electromagnetic spectrum through engineering and administrative tools and procedures.

6.3. **Cybersecurity** – The ability to protect, defend and restore information and information systems, including Platform Information Technology (PIT).

6.3.1. **Information Exchange Security** – The ability to secure dynamic information flow within and across domains.

6.3.2. **Networks Protection** – The ability to anticipate and prevent successful cyberspace threat incidents on networks.

6.3.3. **Data Protection** – The ability to prevent theft, accidental loss, or corruption of data across applications, networks, and databases.

6.3.4. **Identity & Access Management** – The ability to control access to information systems.

6.3.5. **Application Security** – The ability to secure an application by preventing exceptions to the application's security policy or the underlying information system.

6.3.6. **Cyberspace Survivability** – The ability to mitigate effects of malicious cyberspace activity and resulting system degradation by preserving critical functions performance at threshold levels during a cyberspace threat incident, and then after a cyberspace threat incident recover full functionality within a specified mission-relevant timeframe. Systems include, but are not limited to, enterprise and organizational networks, weapons systems, and critical infrastructures.

6.4. **Defensive Cyberspace Operations (Internal Defensive Measures)** – The ability to defeat on-going or imminent threats to defend DoD cyberspace capabilities through systems actions internal to the DODIN.

6.4.1. **Cyberspace Defense** – The ability to provide defense of networks, to include at the boundary.

6.5. **Enterprise Services** – The ability to provide to all authorized users awareness of and access to all DoD information and DoD-wide information services.

6.5.1. **Information Sharing** – The ability to make information visible, accessible, understandable, trusted, and interoperable via secure physical and virtual access to hosted information and data centers across the enterprise and with mission partners based on established data standards.

6.5.2. **Computing Services** – The ability to process data and provide physical and virtual access to hosted information and data centers across the enterprise based on established data standards.

6.5.3. **Common Enterprise Services** – The ability to provide awareness of, access to and delivery of information on the DODIN via a set of registered services.

6.5.4. **Positioning, Navigation, & Timing** – The ability to determine accurate and precise location, orientation, time and course corrections anywhere in the battlespace and to provide timely and assured PNT services across the DoD enterprise.

7. **Protection** – The ability to preserve the effectiveness and survivability of military and nonmilitary personnel, equipment, facilities, and infrastructure by preventing, mitigating, and ensuring recovery from attacks, CBRN incidents, and other hazards.

7.1. **Prevention** – The ability to avoid or neutralize an imminent or on-going attack on personnel and physical assets.

7.1.1. **Concealment/Stealth** – The ability to prevent detection of personnel or physical assets through active and passive measures.

7.1.2. **Countering Weapons of Mass Destruction** – The ability to curtail the conceptualization, development, possession, proliferation, and use of weapons of mass destruction, related expertise, materials, technologies, and means of delivery.

7.1.3. **Counter Air & Missile** – The ability to neutralize imminent and on-going attacks by air and missile threats.

7.1.4. **Physical Security** – The ability to prevent unauthorized access to personnel, equipment, installations, and information, and to safeguard them against espionage, sabotage, terrorism, damage, and criminal activity.

7.2. **Mitigation** – The ability to minimize the effects and manage the consequence of attacks and designated emergencies on personnel and physical assets.

7.2.1. **Explosive** – The ability to minimize the effects of explosives attacks on personnel and physical assets.

7.2.2. **Projectile** – The ability to minimize the effects of projectile attacks on personnel and physical assets.

7.2.3. **Chemical** – The ability to minimize the effects of chemical attacks and emergencies on personnel and physical assets.

7.2.4. **Biological** – The ability to minimize the effects of biological attacks and emergencies on personnel and physical assets.

7.2.5. **Radiological** – The ability to minimize the effects of radiological attacks and emergencies on personnel and physical assets.

7.2.6. **Nuclear** – The ability to minimize the effects of nuclear attacks on personnel and physical assets.

7.2.7. **Electromagnetic Effects** – The ability to minimize the effects of electromagnetic interference, electromagnetic pulse, and other electromagnetic hazards.

7.2.8. **Directed Energy** – The ability to minimize the effects of directed energy attacks on personnel and physical assets.

7.2.9. **Natural Hazards** – The ability to minimize the effects of natural hazards on personnel and physical assets.

7.3. **Recovery** – The ability to remove remaining hazards from the operational environment.

7.3.1. **CBRN Response** – The ability to neutralize, contain, or minimize the effects of a CBRN incident.

7.3.2. **Maritime Counter-Mine** – The ability to clear a mined area in the maritime domain.

8. **Corporate Management & Support** – The ability to provide strategic senior level, enterprise-wide leadership, direction, coordination, and oversight through a chief management officer function.

8.1. **Advisory & Compliance** – The ability to ensure compliance with statutory, regulatory, and policy requirements and to propose changes to those requirements.

8.1.1. **Legal Advice** – The ability to support decision makers on all civil, acquisition, fiscal, military, international, and operational law issues.

8.1.2. **Legislative Advice** – The ability to advise and assist DoD leaders on all issues involving Congressional testimony or reporting.

8.1.3. **Audit, Inspection, & Investigation** – The ability to understand and monitor matters relating to effective operations of DoD with particular regard to internal review activities.

8.1.4. **Personnel Security Investigations & Clearance Certification** – The ability to assess and certify the reliability and credibility of individuals to hold a particular security clearance.

8.1.5. **Operational Test & Evaluation** – The ability to assess systems for their operational effectiveness, suitability, and survivability in relevant operational environments.

8.2. **Strategic Management** – The ability to establish the direction and priority of activities of the DoD.

8.2.1. **Strategy Development** – The ability to establish DoD direction, strategic goals, priorities, objectives, guidance, and total force capability requirements.

8.2.2. **Capability Development** – The ability to identify, validate, and prioritize capability requirements and associated capability gaps.

8.2.3. **Performance Management** – The ability to direct, supervise, advise, formulate policy, analyze, evaluate, and recommend performance measures/targets that support the DoD mission, strategic goals, objectives, priorities, and policies.

8.2.4. **Enterprise Risk Management** – The ability to identify, analyze, and evaluate risks using a structured and systematic approach to recognize where the potential for undesired outcomes or opportunities can arise, including the ability to develop alternatives, responds to risks, and monitor and review performance.

8.2.5. **Studies & Analyses** – The ability to conduct reviews with appropriate rigor to support decision making for policy development, management, and administration of DoD capabilities, programs and activities.

8.2.6. **Enterprise Architecture** – The ability to develop, implement, and maintain an Enterprise Architecture to guide the development of integrated warfighting and business capabilities within DoD and guide, constrain, and permit implementation of interoperable defense systems and solutions.

8.3. **Information Management** – The ability to establish and oversee policies, standards, and assessment mechanisms for organization, security, access, and storage of data, information, and Information Technology architectures.

8.4. **Acquisition & Technology** – The ability to provide materiel for DoD operations.

8.4.1. **Research** – The ability to conduct fundamental research, science, technology, development and experimentation for all DoD capabilities and operations.

8.4.2. **Advanced Technology** – The ability to produce innovative and unique components and prototypes that can be integrated into defense systems for field experiments and/or tests in a simulated or operational environments to assess military utility.

8.4.3. **Developmental Engineering** – The ability to design and build DoD weapons and other systems, including the ability to conduct developmental testing.

8.4.4. **Acquisition Management** – The ability to manage DoD and Industry activities to acquire materiel for DoD operations. This includes program initiation, contracting, portfolio system acquisition, production and lifecycle acquisition, and capability termination and disposal.

8.5. **Financial Management** – The ability to direct, supervise, provide advice, formulate policy, and conduct analysis on DoD program, budget, performance, and financial matters.

8.5.1. **Programming & Budgeting** – The ability to direct, supervise, advise, formulate policy, analyze, evaluate, and recommend efficient and effective resource allocation and performance targets/metrics that support DoD missions, strategic goals, objectives, priorities, and approved strategies and policies including the ability to direct, formulate, justify, and present the costs, efficiency, effectiveness, and capabilities of DoD programs and Defense budgets timely and accurately.

8.5.2. **Accounting & Finance** – The ability to supervise, direct, advise, formulate policy, and account for the execution of DoD resources, including preparation of auditable financial statements. The ability to direct, supervise, and operate integrated DoD accounting and financial management systems and manage and execute financial operations that provide common DoD support in the areas of finance (payroll, commercial pay, etc.), and accounting.

Appendix B. Final SBIR Data Set

TOP_NO	Commercialized	FK Grade	JCA	Woman_Owned	Number_Employees	DUNS	Total_Awards
A09-004	0	12.7	71	0	136	073800062	7
A09-099	0	19.1	81	0	35	787796853	2
A11-028	0	20.4	23	0	44	883336190	9
AF03T017	0	14.9	43	0	14	111487588	12
AF05-093	1	18.2	61	0	93	151209723	71
AF05-131	0	14.2	31	0	5	192267743	4
AF05-265	0	15.6	43	0	57	555403328	68
AF06-019	0	16.9	72	0	30	192467199	2
AF06-320	0	15.7	84	0	6	883221723	6
AF071-117	0	17.3	43	0	73	788133387	12
AF071-213	1	13.7	71	0	71	044329761	27
AF071-320	0	13.5	43	1	130	127283500	34
AF073-105	0	15.3	42	0	7	787026918	5
AF073-142	0	16.5	84	0	3	037658379	4
AF083-198	0	11.9	31	0	15	014886549	6
AF083-254	0	15.4	81	0	36	015334899	25
AF093-025	0	16.6	52	0	80	124032868	30
AF093-070	0	16.1	84	0	45	184629491	43
AF093-114	0	14.6	43	0	40	796010411	151
AF093-165	0	14	31	0	4	086508335	4
AF093-191	0	13.8	42	0	9	058268652	11
AF093-208	0	20.1	43	1	30	157955597	17
AF093-216	0	17.6	31	0	10	623702557	5
AF09-BT22	1	22.1	84	0	12	148034408	31
AF103-017	0	20.5	23	0	3	828069190	4
AF103-064	0	20	24	0	49	956324362	40
AF103-088	1	20.7	24	0	41	078716100	51
AF103-089	0	14.1	31	0	15	014886549	6
AF103-102	0	16.4	31	0	115	826940673	6
AF103-180	0	15.4	46	0	340	053885604	1
AF103-198	0	17.6	43	0	34	015334899	25
AF103-208	0	21.1	84	0	42	161183322	25
AF103-209	0	15.8	31	0	482	604717165	24
AF103-224	0	16.1	31	1	30	129074840	35
AF103-240	0	13.1	43	0	196	073804411	42
AF103-253	0	15.9	43	1	393	153865951	419
AF112-026	0	24.8	24	0	25	964730451	26
AF112-043	1	15	31	0	18	199060521	17
AF112-055	1	23.7	62	1	7	967349668	9
AF112-097	0	18	32	0	24	602414141	6

AF112-170	0	17.7	31	0	12	829299747	5
AF112-219	0	20.4	47	0	2	030895580	4
AF11-BT25	0	14.3	43	1	125	185169620	151
AF121-050	0	16.8	23	0	42	038379579	27
AF121-095	0	15.1	72	0	25	055775803	18
AF121-097	0	16.4	72	0	30	131277725	13
AF121-156	0	14.1	61	0	5	784427200	5
AF121-170	0	17.2	43	1	12	094142122	21
AF121-189	0	14.6	31	0	25	126112387	16
AF121-212	1	14.5	42	0	100	053254546	2
AF121-225	0	16.1	43	1	31	197187602	59
AF131-023	0	18.4	24	0	30	002548290	3
AF131-038	0	15.6	23	0	61	111305843	20
AF131-045	0	15.8	61	0	20	609444302	10
AF131-050	1	16.2	61	0	5	827005385	3
AF131-052	0	20.9	63	0	76	101321479	34
AF131-057	0	17.5	42	0	1	035982399	1
AF131-060	1	16.4	61	0	15	158217203	2
AF131-062	0	14	65	1	20	182097444	46
AF131-066	0	16	72	0	25	179492566	24
AF131-067	0	14.6	31	0	27	829274674	1
AF131-069	0	14.3	53	0	40	608176715	75
AF131-074	0	21.6	31	0	10	830487414	6
AF131-077	0	17.3	31	0	65	126288336	17
AF131-079	0	15	61	1	115	125961123	68
AF131-082	0	19.8	31	0	2	078375455	1
AF131-131	0	15.8	31	0	37	964928464	30
AF131-135	0	15.5	22	1	3	078869266	1
AF131-139	0	15.1	23	0	25	179492566	24
AF131-142	0	15.4	61	0	12	805473951	7
AF131-158	0	13.4	31	0	37	178154456	20
AF131-159	0	18.2	31	0	10	829299747	5
AF131-160	0	16.1	31	0	5	615345329	4
AF131-163	0	15.2	43	0	2	154920201	5
AF131-167	0	18.3	31	0	19	148034408	31
AF131-169	0	17.6	31	1	190	048159342	15
AF131-170	0	18.1	31	0	48	184629491	43
AF131-175	0	14.7	31	0	3	784424819	2
AF131-176	0	15.6	84	0	21	100651798	34
AF131-177	0	11.5	32	0	120	054672662	116
AF131-180	0	16.5	84	0	45	794350025	25
AF131-181	1	18.1	84	0	25	018413208	6
AF131-182	0	13.8	31	1	3	078681958	1
AF131-185	0	16.9	84	0	14	038336723	20

AF131-188	0	17	22	0	10	029564965	3
AF131-190	0	17.7	43	1	130	127283500	34
AF131-192	0	15.1	43	0	5	796535776	3
AF131-196	0	15.2	43	1	104	127283500	34
AF131-198	0	14.2	43	0	19	877299446	37
AF131-199	1	14.5	43	0	110	144540283	44
AF131-202	0	14.4	43	0	35	174716618	8
AF131-203	0	15	43	0	5	618754360	1
AF131-206	0	15.1	43	0	114	627132913	166
AF13-AT10	0	20.8	23	1	16	967349668	9
AF141-001	0	16.1	31	1	200	074689217	48
AF141-002	0	16.8	84	1	4	079243008	1
AF141-003	0	16.6	22	0	4	078876627	1
AF141-004	0	19.7	84	0	3	088468702	4
AF141-006	0	19.1	84	0	110	144540283	44
AF141-009	0	14.2	61	0	13	062674630	7
AF141-012	1	17.5	21	0	24	176086952	7
AF141-015	0	16.8	21	0	14	110592016	3
AF141-016	0	15.8	23	0	24	176086952	7
AF141-021	0	16.1	84	1	2	080446447	2
AF141-024	0	15	12	0	40	796010411	151
AF141-025	0	17.8	12	0	340	077317766	39
AF141-027	0	18.5	84	0	8	601628717	6
AF141-028	0	21.4	72	0	110	144540283	44
AF141-029	0	16.4	84	0	20	808473453	1
AF141-030	0	17	12	0	145	115243701	199
AF141-031	1	17.2	12	0	47	009485124	53
AF141-032	0	15.6	62	1	145	161911532	175
AF141-038	0	20.8	64	0	16	803826465	5
AF141-039	0	17.9	63	0	170	069318803	1
AF141-040	0	18.1	63	0	25	179492566	24
AF141-041	0	17.1	65	1	145	161911532	175
AF141-044	0	14.1	65	1	145	161911532	175
AF141-046	0	17.8	62	1	145	161911532	175
AF141-048	0	19.8	25	1	298	153865951	419
AF141-049	0	17.8	62	0	75	052062833	55
AF141-054	0	17.9	23	0	160	036593457	43
AF141-055	0	18.5	23	0	56	964928464	30
AF141-056	0	15.2	84	0	5	062602982	2
AF141-057	0	14.6	53	1	115	556397615	31
AF141-058	0	14.2	63	0	4	869458716	2
AF141-063	0	18.8	43	0	10	188465819	63
AF141-065	0	15.3	43	0	14	111487588	12
AF141-066	0	16.5	43	0	11	182103291	12

AF141-068	0	16	31	1	25	831535674	1
AF141-070	0	17.6	84	0	150	073800062	7
AF141-072	0	16.4	31	0	16	199060521	17
AF141-073	0	18.5	43	0	27	782766831	29
AF141-075	0	15.1	43	0	6	128193997	21
AF141-080	0	19.3	84	0	100	175302579	75
AF141-081	0	16.7	81	0	7	969082747	2
AF141-082	0	14.3	84	0	110	144540283	44
AF141-083	0	14	84	0	14	149341534	1
AF141-084	0	17.4	84	1	85	185169620	151
AF141-086	0	12.3	31	0	35	793187670	11
AF141-091	1	16.2	84	0	12	078449586	1
AF141-092	0	18.2	63	0	60	603978321	31
AF141-094	0	16.8	65	0	45	964928464	30
AF141-096	0	20.2	84	0	40	826034550	4
AF141-097	0	20.8	61	0	4	020977074	2
AF141-099	0	18.2	65	0	120	054672662	116
AF141-100	1	18	65	0	28	153869896	48
AF141-101	1	19.5	23	0	24	196387851	8
AF141-105	0	16.2	23	0	120	054672662	116
AF141-106	0	13.6	84	0	106	010034598	4
AF141-109	0	16.8	61	0	55	134159925	4
AF141-110	0	14	65	0	45	162344035	11
AF141-111	0	20.1	65	1	15	611493458	2
AF141-113	0	16.1	65	0	29	153869896	48
AF141-121	0	15.3	24	0	280	081475873	26
AF141-122	0	15.2	65	1	21	182097444	46
AF141-123	0	16.6	23	0	28	825470987	10
AF141-124	0	24.2	61	0	200	112803689	2
AF141-125	0	13.8	65	0	23	145051095	32
AF141-126	0	15.1	65	0	15	014750785	17
AF141-129	0	14.8	32	0	12	066502142	5
AF141-130	0	13.9	32	0	285	082191198	88
AF141-132	0	14.4	65	0	17	160209102	28
AF141-133	0	14.4	65	0	280	081475873	26
AF141-134	0	19.1	32	0	20	191741292	20
AF141-135	0	15.3	32	0	280	081475873	26
AF141-136	0	15.2	32	0	135	107940207	28
AF141-137	0	18.8	32	1	85	185169620	151
AF141-138	0	16.2	32	0	55	086581902	16
AF141-139	0	21.3	32	0	52	064390719	32
AF141-141	0	16.3	32	0	20	131277725	13
AF141-142	0	17.6	32	0	15	114322076	14
AF141-143	0	19.6	84	1	50	006468131	4

AF141-144	0	17	71	0	48	363384004	1
AF141-145	0	17.2	32	0	23	617058602	10
AF141-151	0	19.7	84	0	65	009934576	3
AF141-152	0	18.9	43	0	12	800669884	3
AF141-156	0	14.7	43	1	6	960861958	4
AF141-157	0	18.4	43	0	3	969331193	6
AF141-158	0	15.1	43	0	4	832003045	3
AF141-159	0	14.2	43	1	298	153865951	419
AF141-160	0	15.3	43	0	10	173666215	14
AF141-161	0	13.3	43	1	145	161911532	175
AF141-163	0	18.4	84	0	13	961869364	3
AF141-165	0	17.5	43	0	20	187594788	20
AF141-167	0	16.4	43	1	3	968246939	1
AF141-175	0	20.5	84	0	40	062167416	4
AF141-177	0	16.7	24	0	125	107940207	28
AF141-178	0	15.9	22	0	46	119301831	67
AF141-179	1	14.8	22	0	25	179492566	24
AF141-180	0	13	22	0	15	602673188	18
AF141-181	0	14	31	0	75	052062833	55
AF141-182	0	14.5	22	0	25	179492566	24
AF141-183	0	18.1	22	0	48	047627732	80
AF141-184	1	16.7	22	1	2	614146764	5
AF141-185	0	18.1	43	0	24	181660775	4
AF141-186	0	13.4	23	0	170	107939233	35
AF141-187	0	13.4	23	1	42	131860632	14
AF141-190	0	15.2	61	0	5	827005385	3
AF141-192	0	19.1	61	0	8	619085371	10
AF141-193	0	19.8	61	0	8	623981375	1
AF141-194	0	20.4	61	1	6	796754315	6
AF141-195	0	19.2	23	0	18	788293244	6
AF141-196	0	15.2	22	0	31	124348652	39
AF141-197	0	17.1	23	0	43	363384004	1
AF141-198	0	18.2	22	0	100	841440832	28
AF141-199	0	16.1	22	0	35	120669085	5
AF141-203	0	13.4	43	1	130	127283500	34
AF141-204	0	15.5	43	0	6	831164822	2
AF141-205	0	12.3	43	0	119	627132913	166
AF141-206	0	17.1	43	0	5	194937939	2
AF141-207	0	15.4	43	0	130	625120902	85
AF141-211	0	15.6	46	0	5	078808915	7
AF141-212	0	16.8	43	0	156	793274747	10
AF141-214	0	17.8	31	0	468	604717165	24
AF141-222	0	15.4	84	0	90	126288336	17
AF141-226	1	21.5	84	1	97	185169620	151

AF141-227	0	13.5	84	0	50	555403328	3
AF141-228	0	16.7	84	0	100	884812025	30
AF141-229	0	17.2	84	0	1	078428610	1
AF141-230	0	15.7	84	1	85	185169620	151
AF141-231	0	14.9	84	0	6	153008631	4
AF141-243	0	13.1	65	1	110	125961123	68
AF141-244	0	19.9	24	1	10	967349668	9
AF141-248	0	19	24	0	280	048384205	1
AF141-250	0	13.8	84	0	150	844118195	4
AF141-251	0	14.2	65	0	22	196387851	8
AF141-252	0	16.8	65	0	6	787644921	15
AF141-253	0	16.2	65	0	334	053885604	93
AF151-009	0	21.4	73	0	3	080260501	1
AF151-010	1	18.5	72	0	160	085851181	5
AF151-011	0	17.5	72	0	8	964423326	3
AF151-012	0	12.9	32	1	8	610359684	2
AF151-013	0	18.8	32	0	48	602959579	26
AF151-015	0	16.4	32	0	45	602262222	11
AF151-016	0	16.5	22	0	285	829000723	2
AF151-017	0	19.2	31	0	21	133092291	4
AF151-018	0	19.5	22	1	289	153865951	419
AF151-019	0	17.8	72	1	13	361680049	6
AF151-020	0	19.4	31	1	289	153865951	419
AF151-021	0	16.9	13	0	6	784426954	5
AF151-022	0	16.3	48	0	183	184758308	99
AF151-023	1	20.1	31	0	15	933302655	6
AF151-025	0	16.1	23	0	3	833083749	2
AF151-026	0	15.3	84	1	12	808480086	4
AF151-029	0	19.3	64	0	63	098009918	14
AF151-030	0	17.7	64	0	4	869458716	2
AF151-034	0	20.9	23	1	16	967349668	9
AF151-036	0	17.1	64	1	165	161911532	175
AF151-038	0	18.4	64	0	83	101321479	34
AF151-040	1	15.7	23	0	5	131070141	3
AF151-042	1	17.3	23	0	120	809180151	7
AF151-045	1	20.7	65	0	114	797735883	20
AF151-047	0	17.9	52	0	113	964928464	30
AF151-048	0	16.3	52	0	50	038379579	27
AF151-050	0	18.6	22	0	14	159048698	8
AF151-051	0	15.5	43	0	18	199060521	17
AF151-056	0	22	31	0	38	927606251	12
AF151-059	0	18	84	1	229	048159342	15
AF151-060	0	20.4	65	0	15	078825979	1
AF151-061	1	13.8	31	0	6	005594908	5

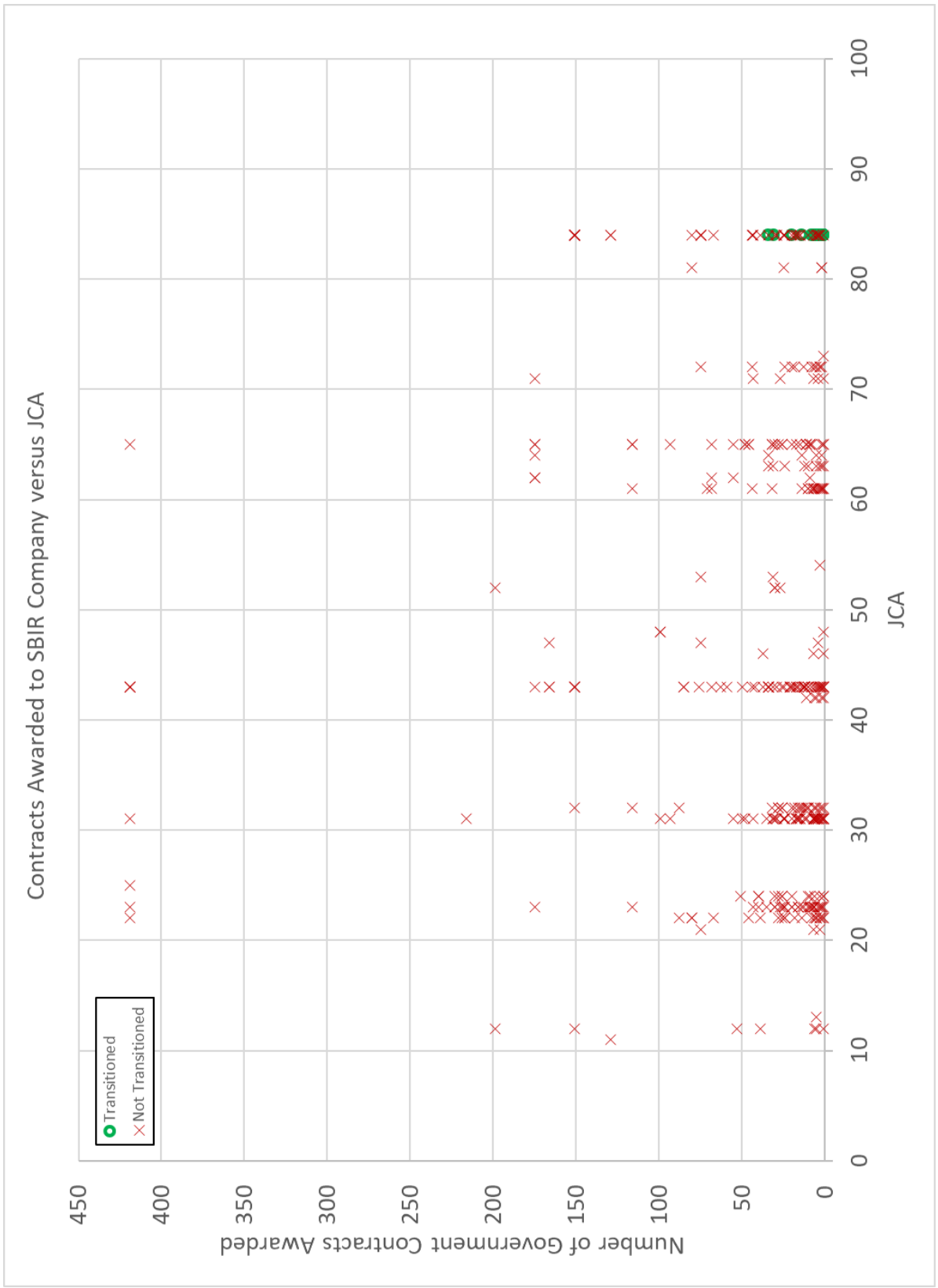
AF151-062	0	15.6	31	0	22	144158677	6
AF151-063	0	20.4	31	0	30	782766831	29
AF151-065	0	12.4	84	0	30	782766831	29
AF151-067	0	14.5	31	1	15	829737688	2
AF151-070	0	17.2	31	0	40	161183322	25
AF151-071	1	17.8	84	0	494	945837219	5
AF151-072	1	14.8	31	0	8	557479073	2
AF151-074	0	13.6	71	1	135	161911532	175
AF151-075	0	16.9	65	0	59	162344035	11
AF151-076	0	15.6	65	0	5	796519630	1
AF151-077	0	18.9	65	0	28	145051095	32
AF151-078	0	18.5	63	0	70	809202018	12
AF151-079	0	19	72	0	40	608176715	75
AF151-080	0	13.1	65	0	24	112697136	9
AF151-081	0	19.9	21	0	40	608176715	75
AF151-082	0	19.4	22	0	13	601975803	6
AF151-083	0	13	24	0	47	956324362	40
AF151-084	0	14.2	31	0	147	072021041	216
AF151-085	0	20.2	31	0	183	184758308	99
AF151-088	0	15	31	0	19	148034408	31
AF151-089	0	12.3	61	0	15	787318828	2
AF151-095	0	13.8	31	0	49	135553472	7
AF151-096	0	17.1	52	0	146	115243701	199
AF151-097	0	18.1	24	0	85	964928464	30
AF151-098	0	18	22	0	78	151471349	14
AF151-101	0	17.2	84	0	82	020817883	24
AF151-102	0	14.4	32	0	104	040707460	28
AF151-103	0	14.3	32	0	3	830813718	6
AF151-105	0	17.9	32	0	87	827121455	15
AF151-106	0	17.3	84	0	25	055775803	18
AF151-107	0	18.4	22	0	259	082191198	88
AF151-108	0	18.7	71	0	154	036593457	43
AF151-109	0	16.2	32	0	5	167202097	10
AF151-111	0	18.3	54	0	80	143980741	3
AF151-114	0	20.1	84	0	25	055775803	18
AF151-118	0	19	84	0	97	185169620	151
AF151-119	0	14.1	84	0	20	078470774	4
AF151-120	0	15.8	84	0	2	964232594	4
AF151-121	0	16.1	43	0	9	128193997	21
AF151-122	0	13.6	43	0	18	018791827	31
AF151-123	0	15.7	43	0	20	043688410	16
AF151-126	1	17.6	84	0	12	123834959	2
AF151-127	0	12.7	48	0	183	184758308	99
AF151-129	0	15.5	43	0	130	625120902	85

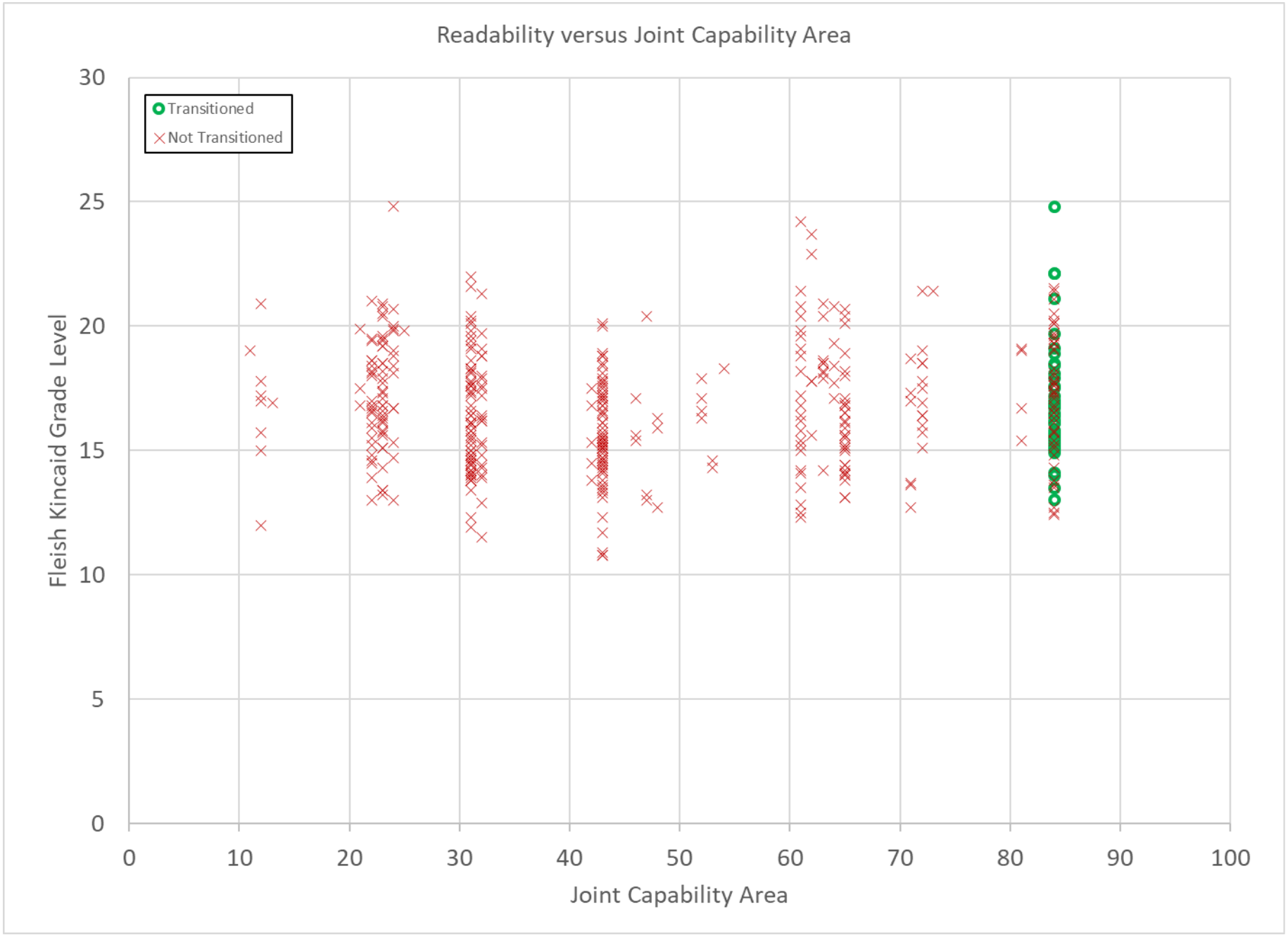
AF151-130	0	17.5	84	0	3	079716398	2
AF151-132	0	22.1	84	0	14	159048698	8
AF151-133	0	19.1	31	0	10	966110350	3
AF151-134	0	18.9	84	0	11	078808915	7
AF151-135	0	18.3	84	0	47	124348652	39
AF151-136	0	15.7	84	0	35	938966090	10
AF151-139	0	21	22	1	2	079637982	3
AF151-141	0	16.8	22	0	39	047627732	80
AF151-142	0	18.5	63	0	50	555403328	3
AF151-143	0	14	32	0	14	602673188	18
AF151-144	0	15.7	72	0	25	187594788	20
AF151-150	0	18.8	61	0	13	079487550	1
AF151-151	0	21.1	84	1	2	614146764	5
AF151-152	0	15.1	84	0	24	009588489	6
AF151-154	0	21.4	61	0	78	151471349	14
AF151-155	0	17.7	84	0	70	612439146	5
AF151-156	0	13.9	22	0	24	964730451	26
AF151-160	0	14.6	43	1	4	361655178	1
AF151-169	0	10.8	43	0	25	148551653	13
AF151-180	0	19.3	84	0	95	086581902	16
AF151-187	0	18.1	84	0	136	133709001	20
AF151-189	0	17.7	84	0	45	076387984	1
AF151-190	0	16.8	84	0	8	078466424	7
AF151-191	0	16.7	84	1	9	134722656	6
AF151-192	1	17.1	84	0	126	073800062	7
AF151-194	0	19.1	84	0	10	962150483	5
AF153-001	0	16.8	23	0	107	010926207	16
AF153-002	0	15	65	0	30	801184982	9
AF153-003	0	15.5	84	0	20	132336426	4
AF153-004	0	13.8	43	0	42	796010411	151
AF161-001	0	13.2	47	0	95	175302579	75
AF161-002	0	17.1	46	0	23	877299446	37
AF161-005	0	24.8	84	1	7	932699192	2
AF161-007	0	16.6	43	1	130	127283500	34
AF161-008	0	10.9	43	0	42	161183322	1
AF161-010	0	15.4	84	0	22	132336426	4
AF161-011	0	13	84	0	11	168596554	14
AF161-014	0	20	43	0	3	080339743	1
AF161-015	0	10.8	43	0	50	555403328	3
AF161-017	0	16.8	43	1	393	153865951	419
AF161-021	0	14.1	43	0	24	033449757	19
AF161-022	0	17.2	43	1	393	153865951	419
AF161-024	0	17.6	84	1	102	185169620	151
AF161-028	0	16.1	84	0	6	942605825	2

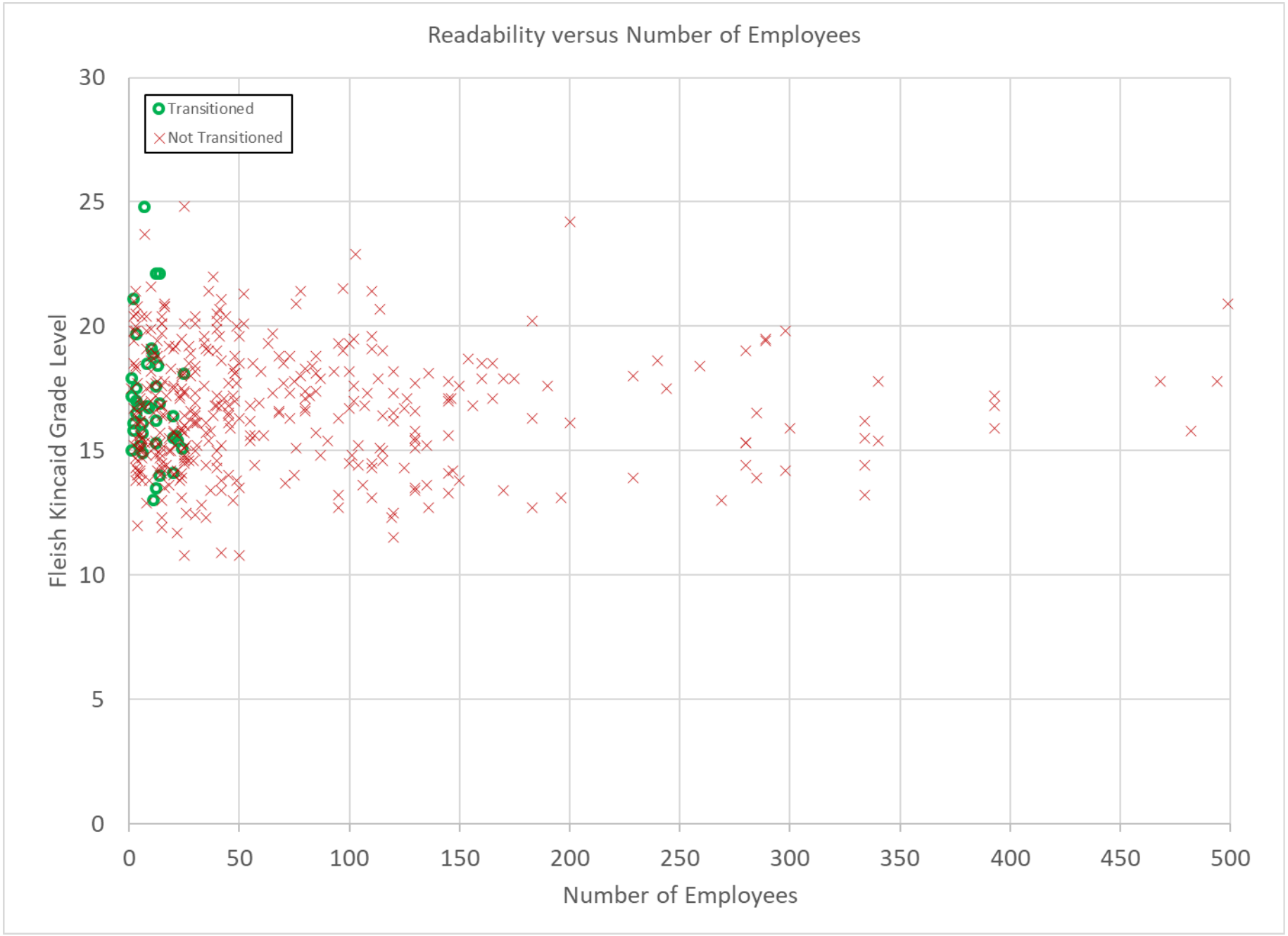
AF161-030	0	19	81	0	36	047627732	80
AF161-033	0	15	84	0	1	078891572	1
AF161-035	0	15.1	23	0	11	079204036	2
AF161-036	0	16.5	84	0	68	119301831	67
AF161-038	1	17.3	84	0	30	014750785	17
AF161-039	0	20.9	12	0	499	945837219	5
AF161-040	0	17.4	23	0	80	124032868	30
AF161-041	1	16.8	84	0	40	608176715	75
AF161-042	0	13.5	84	0	12	080029038	2
AF161-043	0	15.1	84	0	130	967259946	129
AF161-044	0	19.5	84	0	102	185169620	151
AF161-045	0	18.2	23	0	30	103477993	13
AF161-046	0	15.7	12	0	14	157649471	6
AF161-047	0	15.9	48	0	24	079403079	1
AF161-049	0	18.5	23	1	165	161911532	175
AF161-050	0	14.6	22	0	29	120839477	46
AF161-051	0	19.6	61	0	110	144540283	44
AF161-052	0	22.9	62	0	103	125961123	68
AF161-053	0	12.5	61	0	120	054672662	116
AF161-055	0	17.2	61	0	17	834787202	2
AF161-056	0	16.3	23	0	73	111305843	20
AF161-057	0	18.5	72	1	2	079637982	3
AF161-058	0	14.4	31	1	57	800259140	4
AF161-059	0	17.7	23	0	49	956324362	40
AF161-060	0	18.6	63	0	240	085851181	5
AF161-061	0	14.3	23	0	15	079179794	3
AF161-062	0	13.5	61	1	16	013017947	8
AF161-063	0	19.8	24	0	3	078721858	1
AF161-064	0	14.7	43	0	25	964730451	26
AF161-065	1	15.2	31	0	26	081522468	11
AF161-067	0	16.6	31	0	68	130020209	50
AF161-068	0	18.3	31	0	3	079716398	2
AF161-069	0	17	43	0	102	185169620	151
AF161-070	0	19.6	31	0	34	782766831	29
AF161-071	1	19.3	84	0	34	782766831	29
AF161-072	0	17	84	0	3	017391348	6
AF161-073	0	16.3	84	0	95	175302579	75
AF161-074	0	14.8	31	0	101	126288336	17
AF161-075	0	15.2	84	0	42	161183322	25
AF161-076	0	18.6	31	0	42	161183322	25
AF161-077	0	12.7	84	0	95	175302579	75
AF161-078	0	15.6	65	0	55	162344035	11
AF161-079	0	20.4	63	0	8	010681380	10
AF161-080	0	17.5	32	0	244	004475216	1

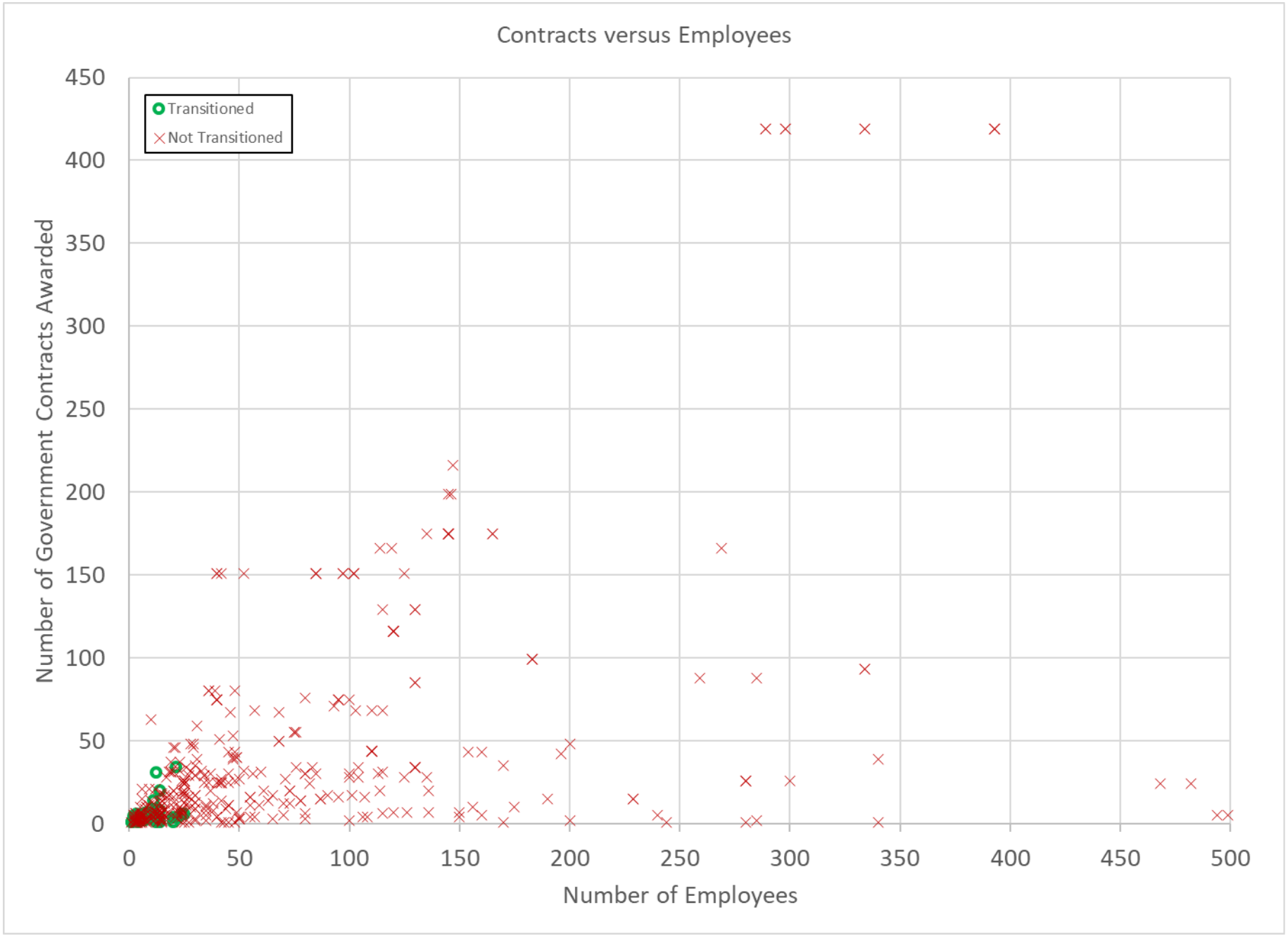
AF161-082	0	12.8	61	0	33	145051095	32
AF161-083	0	16.5	65	0	120	054672662	116
AF161-084	0	15.5	65	1	334	153865951	419
AF161-085	0	16.7	24	0	80	172216827	6
AF161-086	0	16.8	31	0	15	808369792	7
AF161-087	0	16.4	23	0	25	964730451	26
AF161-088	0	19.2	23	0	27	071744143	16
AF161-089	0	12.5	84	0	26	100651798	34
AF161-090	0	15.9	65	0	300	081475873	26
AF161-091	0	16.5	65	0	30	801184982	9
AF161-092	0	21.4	84	0	36	047627732	80
AF161-093	0	20.1	84	0	52	796010411	151
AF161-094	0	17.4	31	0	25	825308732	7
AF161-095	1	17.8	43	0	16	111487588	12
AF161-096	1	18.6	22	0	10	124191292	5
AF161-097	0	16.4	72	0	38	159070825	8
AF161-098	0	15.4	31	0	55	086581902	16
AF161-102	0	19.6	23	0	41	794350025	25
AF161-103	0	19.7	32	0	15	009913562	3
AF161-105	0	13	47	0	269	627132913	166
AF161-114	0	11.7	43	0	22	800669884	3
AF161-116	0	17.9	84	0	1	043071804	1
AF161-124	0	18.8	43	0	68	130020209	50
AF161-127	0	17.1	43	0	80	181947730	76
AF161-130	0	17.9	43	0	175	793274747	10
AF161-131	1	18.8	24	0	73	111305843	20
AF161-139	0	13.2	23	1	334	153865951	419
AF161-141	0	16.8	42	0	15	078602532	6
AF161-144	0	14.4	31	0	334	053885604	93
AF161-145	0	14.8	84	0	87	827121455	15
AF161-149	0	19.4	23	0	2	079720006	2
AF162-007	1	15.5	31	1	6	079132144	1
AF162-D001	0	17.3	71	0	108	079490226	4
N09-T021	0	12	12	0	4	191272694	1
N111-062	0	15.1	65	0	76	052062833	55
N121-078	0	14.7	24	1	14	127802234	10
OSD09-EP2	0	17.6	31	0	20	148034408	31
OSD10-CR1	1	19	11	0	115	967259946	129
OSD13-HS2	0	15.8	84	0	130	967259946	129
OSD13-PR5	0	13.9	31	1	229	048159342	15

Appendix C. Other Analysis (Scatter Plots)




Readability versus Joint Capability Area
Transitioned
Not Transitioned
Fleish Kincaid Grade Level
Joint Capability Area
0
5
10
15
20
25
30
0
10
20
30
40
50
60
70
80
90
100


Readability versus Number of Employees
Transitioned
Not Transitioned
Fleish Kincaid Grade Level
Number of Employees
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
450
500


Contracts versus Employees
Transitioned
Not Transitioned
Number of Government Contracts Awarded
Number of Employees
0
50
100
150
200
250
300
350
400
450
500

Appendix D. R Studio Spreadsheet

Commercialized	FKGr	WO	NE	TA	JCA_1	JCA_2	JCA_3	JCA_4	JCA_5	JCA_6	JCA_7
0	15.7	0	6	6	0	0	0	0	0	0	0
0	16.5	0	3	4	0	0	0	0	0	0	0
0	16.1	0	45	43	0	0	0	0	0	0	0
0	21.1	0	42	25	0	0	0	0	0	0	0
0	15.6	0	21	34	0	0	0	0	0	0	0
0	16.5	0	45	25	0	0	0	0	0	0	0
0	16.9	0	14	20	0	0	0	0	0	0	0
0	16.8	1	4	1	0	0	0	0	0	0	0
0	19.7	0	3	4	0	0	0	0	0	0	0
0	19.1	0	110	44	0	0	0	0	0	0	0
0	16.1	1	2	2	0	0	0	0	0	0	0
0	18.5	0	8	6	0	0	0	0	0	0	0
0	16.4	0	20	1	0	0	0	0	0	0	0
0	15.2	0	5	2	0	0	0	0	0	0	0
0	17.6	0	150	7	0	0	0	0	0	0	0
0	19.3	0	100	75	0	0	0	0	0	0	0
0	14.3	0	110	44	0	0	0	0	0	0	0
0	14	0	14	1	0	0	0	0	0	0	0
0	17.4	1	85	151	0	0	0	0	0	0	0
0	20.2	0	40	4	0	0	0	0	0	0	0
0	13.6	0	106	4	0	0	0	0	0	0	0
0	19.6	1	50	4	0	0	0	0	0	0	0
0	19.7	0	65	3	0	0	0	0	0	0	0
0	18.4	0	13	3	0	0	0	0	0	0	0
0	20.5	0	40	4	0	0	0	0	0	0	0
0	15.4	0	90	17	0	0	0	0	0	0	0
0	13.5	0	50	3	0	0	0	0	0	0	0
0	16.7	0	100	30	0	0	0	0	0	0	0
0	17.2	0	1	1	0	0	0	0	0	0	0
0	15.7	1	85	151	0	0	0	0	0	0	0
0	14.9	0	6	4	0	0	0	0	0	0	0
0	13.8	0	150	4	0	0	0	0	0	0	0
0	15.3	1	12	4	0	0	0	0	0	0	0
0	18	1	229	15	0	0	0	0	0	0	0
0	12.4	0	30	29	0	0	0	0	0	0	0
0	17.2	0	82	24	0	0	0	0	0	0	0
0	17.3	0	25	18	0	0	0	0	0	0	0
0	20.1	0	25	18	0	0	0	0	0	0	0
0	19	0	97	151	0	0	0	0	0	0	0
0	14.1	0	20	4	0	0	0	0	0	0	0

0	15.8	0	2	4	0	0	0	0	0	0	0
0	17.5	0	3	2	0	0	0	0	0	0	0
0	22.1	0	14	8	0	0	0	0	0	0	0
0	18.9	0	11	7	0	0	0	0	0	0	0
0	18.3	0	47	39	0	0	0	0	0	0	0
0	15.7	0	35	10	0	0	0	0	0	0	0
0	21.1	1	2	5	0	0	0	0	0	0	0
0	15.1	0	24	6	0	0	0	0	0	0	0
0	17.7	0	70	5	0	0	0	0	0	0	0
0	19.3	0	95	16	0	0	0	0	0	0	0
0	18.1	0	136	20	0	0	0	0	0	0	0
0	17.7	0	45	1	0	0	0	0	0	0	0
0	16.8	0	8	7	0	0	0	0	0	0	0
0	16.7	1	9	6	0	0	0	0	0	0	0
0	19.1	0	10	5	0	0	0	0	0	0	0
0	15.5	0	20	4	0	0	0	0	0	0	0
0	24.8	1	7	2	0	0	0	0	0	0	0
0	15.4	0	22	4	0	0	0	0	0	0	0
0	13	0	11	14	0	0	0	0	0	0	0
0	17.6	1	102	151	0	0	0	0	0	0	0
0	16.1	0	6	2	0	0	0	0	0	0	0
0	15	0	1	1	0	0	0	0	0	0	0
0	16.5	0	68	67	0	0	0	0	0	0	0
0	13.5	0	12	2	0	0	0	0	0	0	0
0	15.1	0	130	129	0	0	0	0	0	0	0
0	19.5	0	102	151	0	0	0	0	0	0	0
0	17	0	3	6	0	0	0	0	0	0	0
0	16.3	0	95	75	0	0	0	0	0	0	0
0	15.2	0	42	25	0	0	0	0	0	0	0
0	12.7	0	95	75	0	0	0	0	0	0	0
0	12.5	0	26	34	0	0	0	0	0	0	0
0	21.4	0	36	80	0	0	0	0	0	0	0
0	20.1	0	52	151	0	0	0	0	0	0	0
0	17.9	0	1	1	0	0	0	0	0	0	0
0	14.8	0	87	15	0	0	0	0	0	0	0
0	15.8	0	130	129	0	0	0	0	0	0	0
0	19.1	0	35	2	0	0	0	0	0	0	0
0	15.4	0	36	25	0	0	0	0	0	0	0
0	16.7	0	7	2	0	0	0	0	0	0	0
0	19	0	36	80	0	0	0	0	0	0	0
0	21.4	0	3	1	0	0	0	0	0	0	1
0	16.9	0	30	2	0	0	0	0	0	0	1
0	15.1	0	25	18	0	0	0	0	0	0	1
0	16.4	0	30	13	0	0	0	0	0	0	1

0	16	0	25	24	0	0	0	0	0	0	1
0	21.4	0	110	44	0	0	0	0	0	0	1
0	17.5	0	8	3	0	0	0	0	0	0	1
0	17.8	1	13	6	0	0	0	0	0	0	1
0	19	0	40	75	0	0	0	0	0	0	1
0	15.7	0	25	20	0	0	0	0	0	0	1
0	18.5	1	2	3	0	0	0	0	0	0	1
0	16.4	0	38	8	0	0	0	0	0	0	1
0	12.7	0	136	7	0	0	0	0	0	0	1
0	17	0	48	1	0	0	0	0	0	0	1
0	13.6	1	135	175	0	0	0	0	0	0	1
0	18.7	0	154	43	0	0	0	0	0	0	1
0	17.3	0	108	4	0	0	0	0	0	0	1
0	14	1	20	46	0	0	0	0	0	1	0
0	17.1	1	145	175	0	0	0	0	0	1	0
0	14.1	1	145	175	0	0	0	0	0	1	0
0	16.8	0	45	30	0	0	0	0	0	1	0
0	18.2	0	120	116	0	0	0	0	0	1	0
0	14	0	45	11	0	0	0	0	0	1	0
0	20.1	1	15	2	0	0	0	0	0	1	0
0	16.1	0	29	48	0	0	0	0	0	1	0
0	15.2	1	21	46	0	0	0	0	0	1	0
0	13.8	0	23	32	0	0	0	0	0	1	0
0	15.1	0	15	17	0	0	0	0	0	1	0
0	14.4	0	17	28	0	0	0	0	0	1	0
0	14.4	0	280	26	0	0	0	0	0	1	0
0	13.1	1	110	68	0	0	0	0	0	1	0
0	14.2	0	22	8	0	0	0	0	0	1	0
0	16.8	0	6	15	0	0	0	0	0	1	0
0	16.2	0	334	93	0	0	0	0	0	1	0
0	20.4	0	15	1	0	0	0	0	0	1	0
0	16.9	0	59	11	0	0	0	0	0	1	0
0	15.6	0	5	1	0	0	0	0	0	1	0
0	18.9	0	28	32	0	0	0	0	0	1	0
0	13.1	0	24	9	0	0	0	0	0	1	0
0	15	0	30	9	0	0	0	0	0	1	0
0	15.6	0	55	11	0	0	0	0	0	1	0
0	16.5	0	120	116	0	0	0	0	0	1	0
0	15.5	1	334	419	0	0	0	0	0	1	0
0	15.9	0	300	26	0	0	0	0	0	1	0
0	16.5	0	30	9	0	0	0	0	0	1	0
0	15.1	0	76	55	0	0	0	0	0	1	0
0	20.8	0	16	5	0	0	0	0	0	1	0
0	19.3	0	63	14	0	0	0	0	0	1	0

0	17.7	0	4	2	0	0	0	0	0	1	0
0	17.1	1	165	175	0	0	0	0	0	1	0
0	18.4	0	83	34	0	0	0	0	0	1	0
0	20.9	0	76	34	0	0	0	0	0	1	0
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0	18.1	0	25	24	0	0	0	0	0	1	0
0	14.2	0	4	2	0	0	0	0	0	1	0
0	18.2	0	60	31	0	0	0	0	0	1	0
0	18.5	0	70	12	0	0	0	0	0	1	0
0	18.5	0	50	3	0	0	0	0	0	1	0
0	18.6	0	240	5	0	0	0	0	0	1	0
0	20.4	0	8	10	0	0	0	0	0	1	0
0	15.6	1	145	175	0	0	0	0	0	1	0
0	17.8	1	145	175	0	0	0	0	0	1	0
0	17.8	0	75	55	0	0	0	0	0	1	0
0	22.9	0	103	68	0	0	0	0	0	1	0
0	14.1	0	5	5	0	0	0	0	0	1	0
0	15.8	0	20	10	0	0	0	0	0	1	0
0	15	1	115	68	0	0	0	0	0	1	0
0	15.4	0	12	7	0	0	0	0	0	1	0
0	14.2	0	13	7	0	0	0	0	0	1	0
0	20.8	0	4	2	0	0	0	0	0	1	0
0	16.8	0	55	4	0	0	0	0	0	1	0
0	24.2	0	200	2	0	0	0	0	0	1	0
0	15.2	0	5	3	0	0	0	0	0	1	0
0	19.1	0	8	10	0	0	0	0	0	1	0
0	19.8	0	8	1	0	0	0	0	0	1	0
0	20.4	1	6	6	0	0	0	0	0	1	0
0	12.3	0	15	2	0	0	0	0	0	1	0
0	18.8	0	13	1	0	0	0	0	0	1	0
0	21.4	0	78	14	0	0	0	0	0	1	0
0	19.6	0	110	44	0	0	0	0	0	1	0
0	12.5	0	120	116	0	0	0	0	0	1	0
0	17.2	0	17	2	0	0	0	0	0	1	0
0	13.5	1	16	8	0	0	0	0	0	1	0
0	12.8	0	33	32	0	0	0	0	0	1	0
0	18.3	0	80	3	0	0	0	0	1	0	0
0	14.3	0	40	75	0	0	0	0	1	0	0
0	14.6	1	115	31	0	0	0	0	1	0	0
0	16.6	0	80	30	0	0	0	0	1	0	0
0	17.9	0	113	30	0	0	0	0	1	0	0
0	16.3	0	50	27	0	0	0	0	1	0	0
0	17.1	0	146	199	0	0	0	0	1	0	0
0	16.3	0	183	99	0	0	0	1	0	0	0

0	12.7	0	183	99	0	0	0	1	0	0	0
0	15.9	0	24	1	0	0	0	1	0	0	0
0	20.4	0	2	4	0	0	0	1	0	0	0
0	13.2	0	95	75	0	0	0	1	0	0	0
0	13	0	269	166	0	0	0	1	0	0	0
0	15.4	0	340	1	0	0	0	1	0	0	0
0	15.6	0	5	7	0	0	0	1	0	0	0
0	17.1	0	23	37	0	0	0	1	0	0	0
0	14.9	0	14	12	0	0	0	1	0	0	0
0	15.6	0	57	68	0	0	0	1	0	0	0
0	17.3	0	73	12	0	0	0	1	0	0	0
0	13.5	1	130	34	0	0	0	1	0	0	0
0	14.6	0	40	151	0	0	0	1	0	0	0
0	20.1	1	30	17	0	0	0	1	0	0	0
0	17.6	0	34	25	0	0	0	1	0	0	0
0	13.1	0	196	42	0	0	0	1	0	0	0
0	15.9	1	393	419	0	0	0	1	0	0	0
0	14.3	1	125	151	0	0	0	1	0	0	0
0	17.2	1	12	21	0	0	0	1	0	0	0
0	16.1	1	31	59	0	0	0	1	0	0	0
0	15.2	0	2	5	0	0	0	1	0	0	0
0	17.7	1	130	34	0	0	0	1	0	0	0
0	15.1	0	5	3	0	0	0	1	0	0	0
0	15.2	1	104	34	0	0	0	1	0	0	0
0	14.2	0	19	37	0	0	0	1	0	0	0
0	14.4	0	35	8	0	0	0	1	0	0	0
0	15	0	5	1	0	0	0	1	0	0	0
0	15.1	0	114	166	0	0	0	1	0	0	0
0	18.8	0	10	63	0	0	0	1	0	0	0
0	15.3	0	14	12	0	0	0	1	0	0	0
0	16.5	0	11	12	0	0	0	1	0	0	0
0	18.5	0	27	29	0	0	0	1	0	0	0
0	15.1	0	6	21	0	0	0	1	0	0	0
0	18.9	0	12	3	0	0	0	1	0	0	0
0	14.7	1	6	4	0	0	0	1	0	0	0
0	18.4	0	3	6	0	0	0	1	0	0	0
0	15.1	0	4	3	0	0	0	1	0	0	0
0	14.2	1	298	419	0	0	0	1	0	0	0
0	15.3	0	10	14	0	0	0	1	0	0	0
0	13.3	1	145	175	0	0	0	1	0	0	0
0	17.5	0	20	20	0	0	0	1	0	0	0
0	16.4	1	3	1	0	0	0	1	0	0	0
0	18.1	0	24	4	0	0	0	1	0	0	0
0	13.4	1	130	34	0	0	0	1	0	0	0

0	15.5	0	6	2	0	0	0	1	0	0	0
0	12.3	0	119	166	0	0	0	1	0	0	0
0	17.1	0	5	2	0	0	0	1	0	0	0
0	15.4	0	130	85	0	0	0	1	0	0	0
0	16.8	0	156	10	0	0	0	1	0	0	0
0	15.5	0	18	17	0	0	0	1	0	0	0
0	16.1	0	9	21	0	0	0	1	0	0	0
0	13.6	0	18	31	0	0	0	1	0	0	0
0	15.7	0	20	16	0	0	0	1	0	0	0
0	15.5	0	130	85	0	0	0	1	0	0	0
0	14.6	1	4	1	0	0	0	1	0	0	0
0	10.8	0	25	13	0	0	0	1	0	0	0
0	13.8	0	42	151	0	0	0	1	0	0	0
0	16.6	1	130	34	0	0	0	1	0	0	0
0	10.9	0	42	1	0	0	0	1	0	0	0
0	20	0	3	1	0	0	0	1	0	0	0
0	10.8	0	50	3	0	0	0	1	0	0	0
0	16.8	1	393	419	0	0	0	1	0	0	0
0	14.1	0	24	19	0	0	0	1	0	0	0
0	17.2	1	393	419	0	0	0	1	0	0	0
0	14.7	0	25	26	0	0	0	1	0	0	0
0	17	0	102	151	0	0	0	1	0	0	0
0	11.7	0	22	3	0	0	0	1	0	0	0
0	18.8	0	68	50	0	0	0	1	0	0	0
0	17.1	0	80	76	0	0	0	1	0	0	0
0	17.9	0	175	10	0	0	0	1	0	0	0
0	15.3	0	7	5	0	0	0	1	0	0	0
0	13.8	0	9	11	0	0	0	1	0	0	0
0	17.5	0	1	1	0	0	0	1	0	0	0
0	16.8	0	15	6	0	0	0	1	0	0	0
0	18	0	24	6	0	0	1	0	0	0	0
0	11.5	0	120	116	0	0	1	0	0	0	0
0	14.8	0	12	5	0	0	1	0	0	0	0
0	13.9	0	285	88	0	0	1	0	0	0	0
0	19.1	0	20	20	0	0	1	0	0	0	0
0	15.3	0	280	26	0	0	1	0	0	0	0
0	15.2	0	135	28	0	0	1	0	0	0	0
0	18.8	1	85	151	0	0	1	0	0	0	0
0	16.2	0	55	16	0	0	1	0	0	0	0
0	21.3	0	52	32	0	0	1	0	0	0	0
0	16.3	0	20	13	0	0	1	0	0	0	0
0	17.6	0	15	14	0	0	1	0	0	0	0
0	17.2	0	23	10	0	0	1	0	0	0	0
0	12.9	1	8	2	0	0	1	0	0	0	0

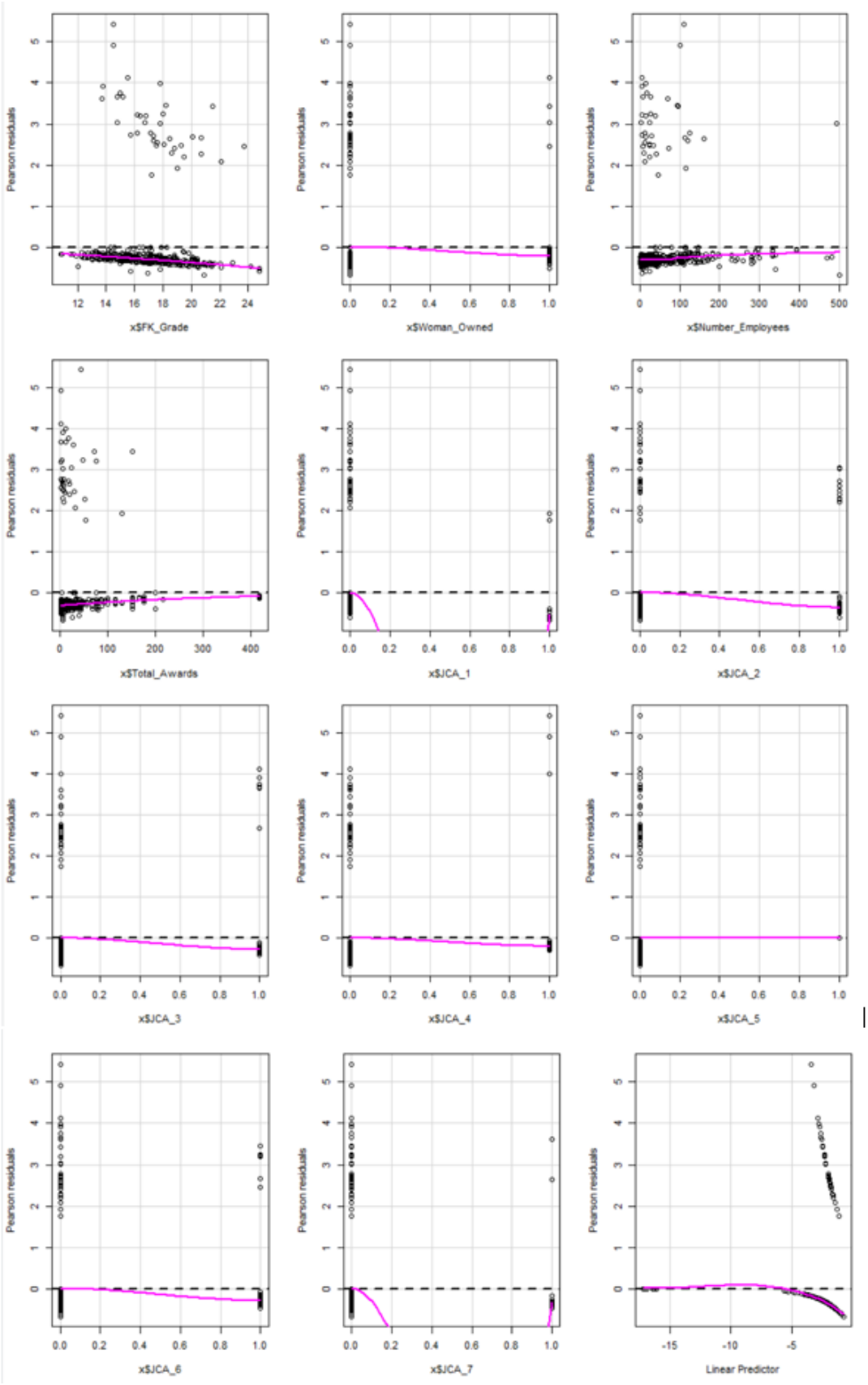
0	18.8	0	48	26	0	0	1	0	0	0	0
0	16.4	0	45	11	0	0	1	0	0	0	0
0	14.4	0	104	28	0	0	1	0	0	0	0
0	14.3	0	3	6	0	0	1	0	0	0	0
0	17.9	0	87	15	0	0	1	0	0	0	0
0	16.2	0	5	10	0	0	1	0	0	0	0
0	14	0	14	18	0	0	1	0	0	0	0
0	17.5	0	244	1	0	0	1	0	0	0	0
0	19.7	0	15	3	0	0	1	0	0	0	0
0	14.2	0	5	4	0	0	1	0	0	0	0
0	11.9	0	15	6	0	0	1	0	0	0	0
0	14	0	4	4	0	0	1	0	0	0	0
0	17.6	0	10	5	0	0	1	0	0	0	0
0	14.1	0	15	6	0	0	1	0	0	0	0
0	16.4	0	115	6	0	0	1	0	0	0	0
0	15.8	0	482	24	0	0	1	0	0	0	0
0	16.1	1	30	35	0	0	1	0	0	0	0
0	17.7	0	12	5	0	0	1	0	0	0	0
0	14.6	0	25	16	0	0	1	0	0	0	0
0	14.6	0	27	1	0	0	1	0	0	0	0
0	21.6	0	10	6	0	0	1	0	0	0	0
0	17.3	0	65	17	0	0	1	0	0	0	0
0	19.8	0	2	1	0	0	1	0	0	0	0
0	15.8	0	37	30	0	0	1	0	0	0	0
0	13.4	0	37	20	0	0	1	0	0	0	0
0	18.2	0	10	5	0	0	1	0	0	0	0
0	16.1	0	5	4	0	0	1	0	0	0	0
0	18.3	0	19	31	0	0	1	0	0	0	0
0	17.6	1	190	15	0	0	1	0	0	0	0
0	18.1	0	48	43	0	0	1	0	0	0	0
0	14.7	0	3	2	0	0	1	0	0	0	0
0	13.8	1	3	1	0	0	1	0	0	0	0
0	16.1	1	200	48	0	0	1	0	0	0	0
0	16	1	25	1	0	0	1	0	0	0	0
0	16.4	0	16	17	0	0	1	0	0	0	0
0	12.3	0	35	11	0	0	1	0	0	0	0
0	14	0	75	55	0	0	1	0	0	0	0
0	17.8	0	468	24	0	0	1	0	0	0	0
0	19.2	0	21	4	0	0	1	0	0	0	0
0	19.4	1	289	419	0	0	1	0	0	0	0
0	22	0	38	12	0	0	1	0	0	0	0
0	15.6	0	22	6	0	0	1	0	0	0	0
0	20.4	0	30	29	0	0	1	0	0	0	0
0	14.5	1	15	2	0	0	1	0	0	0	0

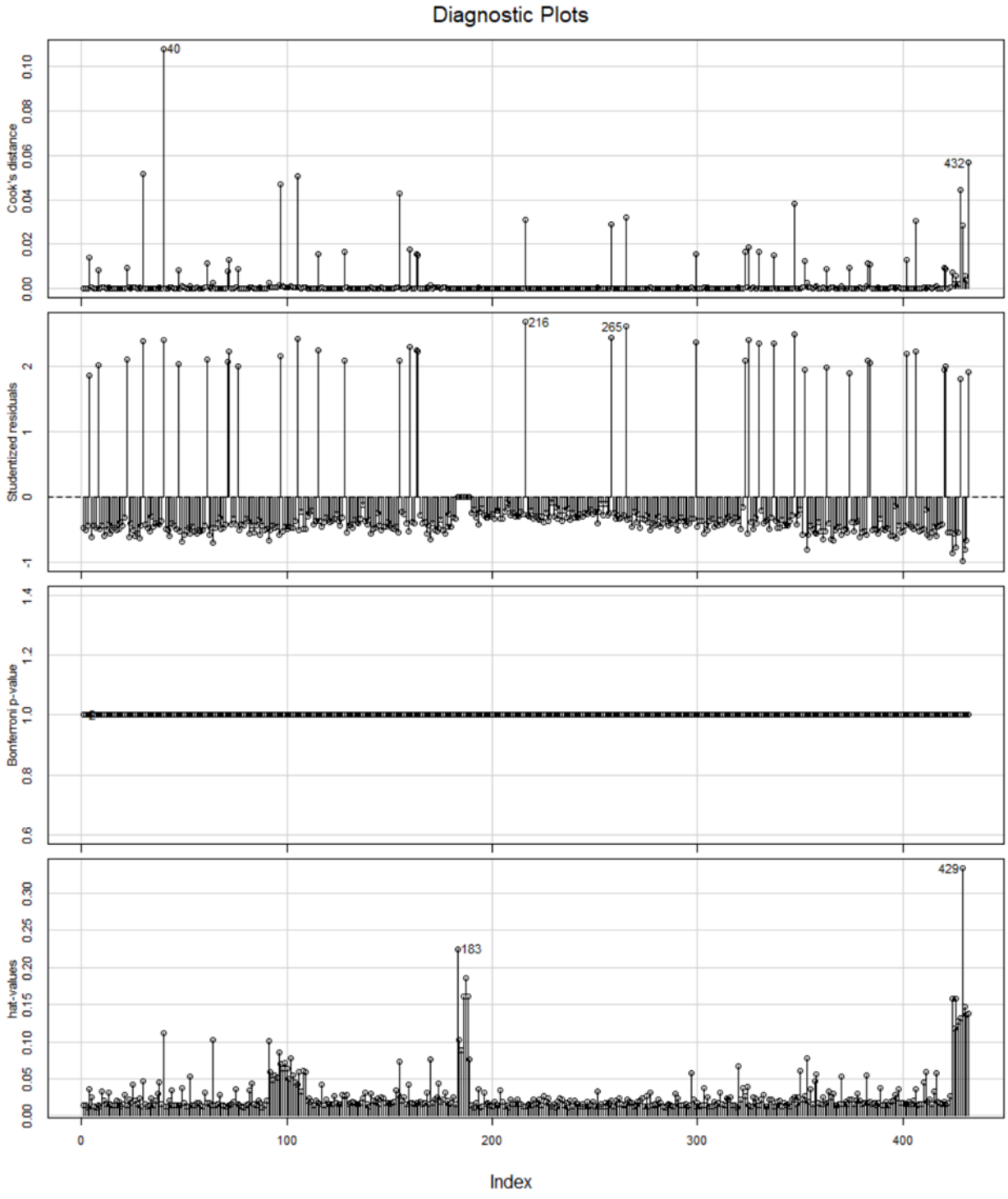
0	17.2	0	40	25	0	0	1	0	0	0	0
0	14.2	0	147	216	0	0	1	0	0	0	0
0	20.2	0	183	99	0	0	1	0	0	0	0
0	15	0	19	31	0	0	1	0	0	0	0
0	13.8	0	49	7	0	0	1	0	0	0	0
0	19.1	0	10	3	0	0	1	0	0	0	0
0	14.4	1	57	4	0	0	1	0	0	0	0
0	16.6	0	68	50	0	0	1	0	0	0	0
0	18.3	0	3	2	0	0	1	0	0	0	0
0	19.6	0	34	29	0	0	1	0	0	0	0
0	14.8	0	101	17	0	0	1	0	0	0	0
0	18.6	0	42	25	0	0	1	0	0	0	0
0	16.8	0	15	7	0	0	1	0	0	0	0
0	17.4	0	25	7	0	0	1	0	0	0	0
0	15.4	0	55	16	0	0	1	0	0	0	0
0	14.4	0	334	93	0	0	1	0	0	0	0
0	17.6	0	20	31	0	0	1	0	0	0	0
0	13.9	1	229	15	0	0	1	0	0	0	0
0	19.8	1	298	419	0	1	0	0	0	0	0
0	20	0	49	40	0	1	0	0	0	0	0
0	24.8	0	25	26	0	1	0	0	0	0	0
0	18.4	0	30	3	0	1	0	0	0	0	0
0	15.3	0	280	26	0	1	0	0	0	0	0
0	16.7	0	125	28	0	1	0	0	0	0	0
0	19.9	1	10	9	0	1	0	0	0	0	0
0	19	0	280	1	0	1	0	0	0	0	0
0	13	0	47	40	0	1	0	0	0	0	0
0	18.1	0	85	30	0	1	0	0	0	0	0
0	19.8	0	3	1	0	1	0	0	0	0	0
0	16.7	0	80	6	0	1	0	0	0	0	0
0	14.7	1	14	10	0	1	0	0	0	0	0
0	20.4	0	44	9	0	1	0	0	0	0	0
0	20.5	0	3	4	0	1	0	0	0	0	0
0	16.8	0	42	27	0	1	0	0	0	0	0
0	15.6	0	61	20	0	1	0	0	0	0	0
0	15.1	0	25	24	0	1	0	0	0	0	0
0	20.8	1	16	9	0	1	0	0	0	0	0
0	15.8	0	24	7	0	1	0	0	0	0	0
0	17.9	0	160	43	0	1	0	0	0	0	0
0	18.5	0	56	30	0	1	0	0	0	0	0
0	16.2	0	120	116	0	1	0	0	0	0	0
0	16.6	0	28	10	0	1	0	0	0	0	0
0	13.4	0	170	35	0	1	0	0	0	0	0
0	13.4	1	42	14	0	1	0	0	0	0	0

0	19.2	0	18	6	0	1	0	0	0	0	0
0	17.1	0	43	1	0	1	0	0	0	0	0
0	16.1	0	3	2	0	1	0	0	0	0	0
0	20.9	1	16	9	0	1	0	0	0	0	0
0	16.8	0	107	16	0	1	0	0	0	0	0
0	15.1	0	11	2	0	1	0	0	0	0	0
0	17.4	0	80	30	0	1	0	0	0	0	0
0	18.2	0	30	13	0	1	0	0	0	0	0
0	18.5	1	165	175	0	1	0	0	0	0	0
0	16.3	0	73	20	0	1	0	0	0	0	0
0	17.7	0	49	40	0	1	0	0	0	0	0
0	14.3	0	15	3	0	1	0	0	0	0	0
0	16.4	0	25	26	0	1	0	0	0	0	0
0	19.2	0	27	16	0	1	0	0	0	0	0
0	19.6	0	41	25	0	1	0	0	0	0	0
0	13.2	1	334	419	0	1	0	0	0	0	0
0	19.4	0	2	2	0	1	0	0	0	0	0
0	15.5	1	3	1	0	1	0	0	0	0	0
0	17	0	10	3	0	1	0	0	0	0	0
0	16.6	0	4	1	0	1	0	0	0	0	0
0	15.9	0	46	67	0	1	0	0	0	0	0
0	13	0	15	18	0	1	0	0	0	0	0
0	14.5	0	25	24	0	1	0	0	0	0	0
0	18.1	0	48	80	0	1	0	0	0	0	0
0	15.2	0	31	39	0	1	0	0	0	0	0
0	18.2	0	100	28	0	1	0	0	0	0	0
0	16.1	0	35	5	0	1	0	0	0	0	0
0	16.5	0	285	2	0	1	0	0	0	0	0
0	19.5	1	289	419	0	1	0	0	0	0	0
0	18.6	0	14	8	0	1	0	0	0	0	0
0	19.4	0	13	6	0	1	0	0	0	0	0
0	18	0	78	14	0	1	0	0	0	0	0
0	18.4	0	259	88	0	1	0	0	0	0	0
0	21	1	2	3	0	1	0	0	0	0	0
0	16.8	0	39	80	0	1	0	0	0	0	0
0	13.9	0	24	26	0	1	0	0	0	0	0
0	14.6	0	29	46	0	1	0	0	0	0	0
0	16.8	0	14	3	0	1	0	0	0	0	0
0	19.9	0	40	75	0	1	0	0	0	0	0
0	16.9	0	6	5	1	0	0	0	0	0	0
0	15	0	40	151	1	0	0	0	0	0	0
0	17.8	0	340	39	1	0	0	0	0	0	0
0	17	0	145	199	1	0	0	0	0	0	0
0	20.9	0	499	5	1	0	0	0	0	0	0

0	15.7	0	14	6	1	0	0	0	0	0	0
0	12	0	4	1	1	0	0	0	0	0	0
1	22.1	0	12	31	0	0	0	0	0	0	0
1	18.1	0	25	6	0	0	0	0	0	0	0
1	16.2	0	12	1	0	0	0	0	0	0	0
1	21.5	1	97	151	0	0	0	0	0	0	0
1	17.8	0	494	5	0	0	0	0	0	0	0
1	17.6	0	12	2	0	0	0	0	0	0	0
1	17.1	0	126	7	0	0	0	0	0	0	0
1	17.3	0	30	17	0	0	0	0	0	0	0
1	16.8	0	40	75	0	0	0	0	0	0	0
1	19.3	0	34	29	0	0	0	0	0	0	0
1	18.5	0	160	5	0	0	0	0	0	0	1
1	13.7	0	71	27	0	0	0	0	0	0	1
1	18	0	28	48	0	0	0	0	0	1	0
1	20.7	0	114	20	0	0	0	0	0	1	0
1	23.7	1	7	9	0	0	0	0	0	1	0
1	18.2	0	93	71	0	0	0	0	0	1	0
1	16.2	0	5	3	0	0	0	0	0	1	0
1	16.4	0	15	2	0	0	0	0	0	1	0
1	14.5	0	110	44	0	0	0	1	0	0	0
1	17.8	0	16	12	0	0	0	1	0	0	0
1	14.5	0	100	2	0	0	0	1	0	0	0
1	15	0	18	17	0	0	1	0	0	0	0
1	20.1	0	15	6	0	0	1	0	0	0	0
1	13.8	0	6	5	0	0	1	0	0	0	0
1	14.8	0	8	2	0	0	1	0	0	0	0
1	15.2	0	26	11	0	0	1	0	0	0	0
1	15.5	1	6	1	0	0	1	0	0	0	0
1	20.7	0	41	51	0	1	0	0	0	0	0
1	18.8	0	73	20	0	1	0	0	0	0	0
1	19.5	0	24	8	0	1	0	0	0	0	0
1	15.7	0	5	3	0	1	0	0	0	0	0
1	17.3	0	120	7	0	1	0	0	0	0	0
1	14.8	0	25	24	0	1	0	0	0	0	0
1	16.7	1	2	5	0	1	0	0	0	0	0
1	18.6	0	10	5	0	1	0	0	0	0	0
1	17.5	0	24	7	0	1	0	0	0	0	0
1	17.2	0	47	53	1	0	0	0	0	0	0
1	19	0	115	129	1	0	0	0	0	0	0

Appendix E. Pearson Residuals Against Predictors and Diagnostic Plots




Diagnostic Plots
Cook's distance
Studentized residuals
Bonferroni p-value
hat-values
Index
40
432
216
265
429
183

Appendix F. Flesch Readability Index Table

Flesch Kinaid Readability Score	Readability Level	Education Level	USA Grade Level	Percentage Adults (Optimistic)
0 – 29	Very difficult	Higher Degrees		5%
30 – 49	Difficult	College		30%
50 – 59	Fairly difficult	Senior High School, A-level	Grade 12	50%
60 – 69	Plain English	13 to 15 year-olds	Grade 7 - 9	80%
70 – 79	Fairly easy	12 year-olds	Grade 6	90%
80 – 89	Easy	11 year-olds.	Grade 5	
90 - 100	Very easy	10 year-olds	Grade 4	

Appendix G. “R Studio” Process

```
> str(xx)
'data.frame':   432 obs. of  12 variables:
 $ Commercialized  : int  0 0 0 1 0 0 0 1 0 0 ...
 $ FK_Grade        : num  15.7 16.5 16.1 22.1 21.1 15.6 16.5 18.1 16.9 16.8 ...
 $ Woman_Owned     : int  0 0 0 0 0 0 0 0 0 1 ...
 $ Number_Employees: int  6 3 45 12 42 21 45 25 14 4 ...
 $ Total_Awards    : int  6 4 43 31 25 34 25 6 20 1 ...
 $ JCA_1           : int  0 0 0 0 0 0 0 0 0 0 ...
 $ JCA_2           : int  0 0 0 0 0 0 0 0 0 0 ...
 $ JCA_3           : int  0 0 0 0 0 0 0 0 0 0 ...
 $ JCA_4           : int  0 0 0 0 0 0 0 0 0 0 ...
 $ JCA_5           : int  0 0 0 0 0 0 0 0 0 0 ...
 $ JCA_6           : int  0 0 0 0 0 0 0 0 0 0 ...
 $ JCA_7           : int  0 0 0 0 0 0 0 0 0 0 ...
> plot(xx$FK_Grade,xx$Commercialized)
> model<-glm(xx$Commercialized~xx$FK_Grade+xx$Woman_Owned+xx$Number_Employees+xx$Total_Awards+xx$JCA_1+xx$JCA_2+xx$JCA_3+xx$J
CA_4+xx$JCA_5+xx$JCA_6+xx$JCA_7,family = binomial(link = "logit"))
> summary(model)

Call:
glm(formula = xx$Commercialized ~ xx$FK_Grade + xx$Woman_Owned +
    xx$Number_Employees + xx$Total_Awards + xx$JCA_1 + xx$JCA_2 +
    xx$JCA_3 + xx$JCA_4 + xx$JCA_5 + xx$JCA_6 + xx$JCA_7, family = binomial(link = "logit"))

Deviance Residuals:
    Min       1Q   Median       3Q      Max
-0.8684  -0.4853  -0.4023  -0.2902   2.6143

Coefficients:
                    Estimate Std. Error z value
(Intercept)         -3.989987   1.309604  -3.047
xx$FK_Grade          0.121164   0.071773   1.688
xx$Woman_Owned      -0.327400   0.565668  -0.579
xx$Number_Employees -0.000714   0.002335  -0.306
xx$Total_Awards     -0.004566   0.004644  -0.983
xx$JCA_1             1.055896   0.911923   1.158
xx$JCA_2             0.101916   0.492671   0.207
xx$JCA_3            -0.383365   0.546581  -0.701
xx$JCA_4            -0.871345   0.688896  -1.265
xx$JCA_5           -14.250346 898.372242  -0.016
xx$JCA_6            -0.299243   0.547112  -0.547
xx$JCA_7            -0.063236   0.824760  -0.077
                   Pr(>|z|)
(Intercept)         0.00231 **
xx$FK_Grade         0.09138 .
xx$Woman_Owned      0.56273
xx$Number_Employees 0.75977
xx$Total_Awards     0.32552
xx$JCA_1            0.24691
xx$JCA_2            0.83612
xx$JCA_3            0.48306
xx$JCA_4            0.20593
xx$JCA_5            0.98734
xx$JCA_6            0.58441
xx$JCA_7            0.93888
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for binomial family taken to be 1)

    Null deviance: 257.30  on 431  degrees of freedom
Residual deviance: 244.34  on 420  degrees of freedom
AIC: 268.34

Number of Fisher Scoring iterations: 15
```

```
> logit_comm = glm(x$Commercialized~.,data = x,family = "binomial")
> tidy(logit_comm)
# A tibble: 12 x 5
   term               estimate std.error statistic p.value
   <chr>                 <dbl>     <dbl>     <dbl>   <dbl>
 1 (Intercept)       -3.99       1.31      -3.05   0.00231
 2 FK_Grade           0.121      0.0718     1.69   0.0914
 3 Woman_Owned       -0.327      0.566     -0.579  0.563
 4 Number_Employees  -0.000714   0.00234   -0.306  0.760
 5 Total_Awards      -0.00457    0.00464   -0.983  0.326
 6 JCA_1              1.06       0.912      1.16   0.247
 7 JCA_2              0.102      0.493      0.207  0.836
 8 JCA_3             -0.383      0.547     -0.701  0.483
 9 JCA_4             -0.871      0.689     -1.26   0.206
10 JCA_5            -14.3      898.        -0.0159 0.987
11 JCA_6             -0.299      0.547     -0.547  0.584
12 JCA_7             -0.0632     0.825     -0.0767 0.939
> effects_logit_comm = margins(logit_comm)
> print(effects_logit_comm)
Average marginal effects
glm(formula = x$Commercialized ~ ., family = "binomial", data = x)

 FK_Grade Woman_Owned Number_Employees Total_Awards
 0.009439     -0.0255       -5.562e-05   -0.0003557
   JCA_1    JCA_2    JCA_3    JCA_4 JCA_5    JCA_6
 0.08226 0.007939 -0.02986 -0.06788 -1.11 -0.02331
    JCA_7
 -0.004926
> summary(effects_logit_comm)
           factor     AME      SE       z      p     lower     upper
         FK_Grade  0.0094  0.0056  1.6715 0.0946   -0.0016    0.0205
            JCA_1  0.0823  0.0712  1.1552 0.2480   -0.0573    0.2218
            JCA_2  0.0079  0.0384  0.2068 0.8361   -0.0673    0.0832
            JCA_3 -0.0299  0.0427 -0.7000 0.4839   -0.1135    0.0538
            JCA_4 -0.0679  0.0541 -1.2542 0.2098   -0.1740    0.0382
            JCA_5 -1.1101 69.9848 -0.0159 0.9873 -138.2779 136.0576
            JCA_6 -0.0233  0.0427 -0.5463 0.5848   -0.1069    0.0603
            JCA_7 -0.0049  0.0643 -0.0767 0.9389   -0.1309    0.1210
 Number_Employees -0.0001  0.0002 -0.3056 0.7599   -0.0004    0.0003
     Total_Awards -0.0004  0.0004 -0.9787 0.3277   -0.0011    0.0004
      Woman_Owned -0.0255  0.0441 -0.5778 0.5634   -0.1120    0.0610
```

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